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|---|---|---|---|---|---|
| Practice 4.10: Simulating Accelerated Motion | PS2.A.a | SP2, SP4, SP5, SP6, SP8 | | | 9-12-PS2-A-1 |
| Reading Page: Using Motion Equations | PS2.A.a | SP1, SP2, SP4, SP5, SP8 | HSA.CED.A.1, HSA.CED.A.2 | | 9-12-PS2-A-1 |
| Practice 4.11: Word Problems - Accelerated Motion | PS2.A.a | SP2, SP4, SP5, SP6, SP8 | HSS. VM.A.2, HSN.VM.A.3, HSA.REI.B.3, HSF.IF.B.4 | MP1, MP2, MP6 | 9-12-PS2-A-1 |
| Reading Page: Using Motion Equations to Generate Graphs | PS2.A.a | SP2, SP4, SP5, SP6, SP8 | HSA.CED.A.1, HSA.CED.A.2, HSF.IF.B4, HSS.ID.B6 | MP1, MP2, MP6 | 9-12-PS2-A-1 |
| Practice 4.12: Motion with Accleration - Data Tables and Graphs | PS2.A.a | SP2, SP4, SP5, SP6, SP8 | HSS. VM.A.2, HSN.VM.A.3, HSA.REI.B.3, HSF.IF.B.4, HSS.ID.B6 | MP1, MP2, MP6 | 9-12-PS2-A-1 |
| Practice 4.13: Motion with Acceleration - Words & Graphs | PS2.A.a | SP2, SP4, SP5, SP6, SP8 | HSS. VM.A.2, HSN.VM.A.3, HSA.REI.B.3, HSF.IF.B.4, HSS.ID.B6, HSS.ID.C7, | MP1, MP2, MP6 | 9-12-PS2-A-1 |
| Practice 4.14: Motion with Acceleration - Stacks of Graphs | PS2.A.a | SP2, SP4, SP5, SP6, SP8 | HSF.IF.B4, HSF.IF.B6, HSF.IF.C7 | | 9-12-PS2-A-1 |
| Two Accelerating Objects - Conceptual Lab | PS2.A.a | SP2, SP3, SP4, SP5 | HSF.IF.B.4, HSF.IF.C.9, HSS.ID. C7, HSF.LE.A.1.b | | 9-12-PS2-A-1 |
| Student Summary Page - Uniform Motion Accelerated Motion | | | | | |
| Testing Cars - Application Lab | PS2.A.a | SP2, SP3, SP4, SP5 | | | 9-12-PS2-A-1 |
| Framing Questions Revisited | | | | | |
| Accelerated Motion Review | | | | | |

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## Exploring Physics Unit 5: Forces and Newton's Laws.Alignment by Activity with Next Generation Science Standards* Disciplinary Core Ideas and Mathematics Common Core Standards§

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| Activity | NGSS Disciplinary Core Ideas (High School) | Science Practices | Math Common Core Standards | Math Practices | MO 2016 |
|---|---|---|---|---|---|
| Exerting Forces Lab | | SP2, SP3, SP4 | | | |
| Reading page: What is a force? | PS2.B.b, PS2.B.c | SP2, SP8 | | | 9-12 PS2- B-4 |
| Broom Ball – The Game Lab | | SP2, SP3, SP4 | | | |
| Reading page: Drawing and Analyzing Forces | | SP2, SP4, SP5 | | | |
| Practice 5.1: Force Challenge | | SP2, SP4, SP5 | | | |
| The Normal Force Lab | | SP2, SP3, SP4, SP5 | | | |
| The Force of Gravity Lab | PS2.B.a, PS2.B.b | SP1, SP2, SP3, SP4, SP5, SP6 | HSA.CED.A.2, HSF.IF.B.6, HSS.ID.B.6, HSS.ID.C.7 | MP4 | 9-12 PS2- B-4 |
| Reading Page: Measuring the Force of Gravity (Weight) | PS2.B.a, PS2.B.b | SP2, SP6, SP8 | HSN.Q.A.1 | | 9-12 PS2- B-4 |
| Practice 5.2: Force of Gravity and its Strength | PS2.B.a, PS2.B.b | SP4, SP5 | HSN.Q.A.1 | | 9-12 PS2- B-4 |

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|---|---|---|---|---|---|
| The Elastic Force Lab | | SP1, SP2, SP3, SP4, SP5, SP6 | HSA.CED.A.2, HSF.IF.B.6, HSS.ID.B.6, HSS.ID.C.7 | MP4 | |
| Practice 5.3: Forces in springs | | SP4, SP5 | HSS.ID.B.6 | | |
| Reading page: Drawing Force Diagrams | | SP2, SP8 | | | |
| Practice 5.4: Force Diagrams | | SP2, SP4, SP5 | | MP2 | |
| Newton’s First Law Lab | | SP2, SP3, SP4, SP6 | | | |
| Reading Page: Newton’s First Law | | SP2, SP8 | | | |
| Practice 5.5: Newton’s First Law | | SP4, SP6 | | | |
| Broom Ball Lab Revisited | | SP2, SP3, SP4 | | | |
| Newton's Third Law Lab | | SP2, SP3, SP4, SP5 | | | |
| Newton’s Third Law Lab with Force Probes | | SP2, SP3, SP4, SP5, SP6 | | | |
| Reading Page: Newton’s Third Law | | SP2, SP8 | | | |
| Practice 5.6: Identifying Pairs of Forces | | SP2, SP4, SP5, SP6 | | MP2 | |
| Newton’s Second Law Lab | | SP2, SP3, SP4, SP5, SP6 | | | |
| Reading Page: Newton’s Second Law | PS2.A.a | SP2, SP8 | HSA.CED.A.2 | | 9-12 PS2-A-1 |
| Practice 5.7: Newton’s Second Law Problems | PS2.A.a | SP2, SP4, SP5, SP6 | HSA.CED.A.1, HSA.CED.A.4 | | 9-12 PS2 - A-1 |
| Practice 5.8: Forces, Motion and Newton’s Laws | | SP2, SP4, SP5 | | MP2 | |

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## Exploring Physics Unit 6: Applications of Newton's Laws: Free Fall and Projectile Motion
## Alignment by Activity with Next Generation Science Standards* Disciplinary Core Ideas and Mathematics Common Core Standards§

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| Activity | NGSS Disciplinary Core Ideas (High School) | Science Practices | Math Common Core Standards | Math Practices | MO 2016 |
|---|---|---|---|---|---|
| Free Fall Lab | PS2.A.a | SP1, SP2, SP3, SP4, SP5, SP6 | HSA.CED.A.1, HSA.CED.A.4, HSF.IF.B.6 , HSS.ID.B.6, HSS.ID.C.7 | MP1, MP2 | 9-12-PS2-A-1 |
| Reading Page: Free Fall | PS2.A.a | SP2, SP4, SP5, SP6, | HSA.CED.A.2 | | 9-12-PS2-A-1 |
| Practice 6.1: Motion of Falling Objects | PS2.A.a | SP5, SP6 | HSA.CED.A.1, HSA.REI.B.3, HSS.ID.B.6 | | 9-12-PS2-A-1 |
| Practice 6.2: Falling Objects - Word Problems | PS2.A.a | SP4, SP5, SP6 | HSN.VM.A.3, HSS.ID.B.6 | | 9-12-PS2-A-1 |
| Throw the Ball Upwards Lab | PS2.A.a | SP1, SP2, SP3, SP4, SP5, SP6 | HSN.VM.A.3, HSA.CED.A.1, HSA.REI.B.3, HSF.IF.B.6, HSS.ID.A.3, HSS.ID.B.6, HSS.ID.C.7 | MP1, MP2, MP4 | 9-12-PS2-A-1 |

| | | | | | |
|---|---|---|---|---|---|
| Reading Page: Up and Down Under Gravity | PS2.A.a | SP2, SP4, SP5, SP6, SP8 | HSN.Q.A.1 | | 9-12-PS2-A-1 |
| Practice 6.3: What Goes Up, Must Come Down | PS2.A.a | SP5, SP6 | HSA.CED.A.1, HSA.REI.B.3, HSS.ID.B.6 | | 9-12-PS2-A-1 |
| Practice 6.4: What Goes Up, Must Come Down Word Problems | PS2.A.a | SP4, SP5, SP6 | HSN.VM.A.3, HSA.CED.A.1, HSA.REI.B.3, HSF.IF.B.6, HSS.ID.A.3, HSS.ID.B.6, HSS.ID.C.7 | MP1, MP2, MP6 | 9-12-PS2-A-1 |
| Practice 6.5: Simulating Motion Under Gravity | PS2.A.a | SP4, SP5, SP6 | HSN.VM.A.3, HSS.ID.B.6 | | 9-12-PS2-A-1 |
| Reading Page – Newtons Law of Universal Gravity | PS2.B.a | SP2, SP5 | HSA.CED.A.1, HSA.REI.B.3, HSS.ID.B.6 | | 9-12-PS2-A-1 |
| Practice 6.6: Gravity on other planets | PS2.B.a | SP4, SP5, SP6 | HSN.VM.A.3, HSA.CED.A.1, HSA.REI.B.3, HSF.IF.B.6 , HSS.ID.A.3, HSS.ID.B.6, HSS.ID.C.7 | MP1, MP2, MP6 | 9-12-PS2-A-1 |
| Student Summary Page: Up and Down | | | | | 9-12-PS2-A-1 |
| Motion in Two Dimensions Lab | PS2.A.a | SP2, SP3, SP4, SP5, SP6 | | MP2 | 9-12-PS2-A-1 |
| Horizontally Launced Projectile Lab | PS2.A.a | SP2, SP3, SP4, SP5, SP6 | HSN.VM.A.3, HSA.CED.A.1, HSS.ID.B.6, HSS.ID.B.6.c | MP4 | 9-12-PS2-A-1 |
| Reading Page: Motion in Two Dimensions - I | PS2.A.a | SP2, SP4, SP5, SP6, SP8 | HSN.Q.A.1, HSN.VM.A.3, HSA.CED.A.2 | MP2 | 9-12-PS2-A-1 |
| Practice 6.7 Motion in 2 Dimensions | PS2.A.a | SP4, SP5, SP6 | HSA.CED.A.1, HSA.REI.B.3, HSS.ID.B.6 | MP2 | 9-12-PS2-A-1 |
| Practice 6.8: Motion in 2 Dimensions Word Problems | PS2.A.a | SP4, SP5, SP6 | HSN.VM.A.3, HSA.CED.A.1, HSA.REI.B.3 | MP1, MP2 | 9-12-PS2-A-1 |
| Practice 6.9: Simulating Projectile Motion I | PS2.A.a | SP4, SP5, SP6 | HSA.CED.A.1, HSA.REI.B.3, HSS.ID.B.6 | MP2 | 9-12-PS2-A-1 |

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|---|---|---|---|---|---|
| Student Summary Page: Free Fall and Projectile Motion | | | | | |
| Forces and Projectile Motion Conceptual Lab | PS2.A.a | SP4, SP5, SP6 | | MP2 | 9-12-PS2-A-1 |
| Hit theTarget Lab-Practicum | PS2.A.a | SP2, SP3, SP4, SP5, SP6 | HSN.VM.A.3, HSA.CED.A.1 | MP4 | 9-12-PS2-A-1 |
| Student Summary Page: Comparing Free Fall to Projectile Motion | | | | | |
| Launching Darts Lab | PS2.A.a | SP1, SP2, SP3, SP4, SP5, SP6 | HSS.ID.B.6 | | 9-12-PS2-A-1 |
| Reading Page: Motion in Two Dimensions, II | PS2.A.a | SP2, SP4, SP5, SP6, SP8 | | | 9-12-PS2-A-1 |
| Practice 6.10: Trajectory Challenge | PS2.A.a | SP4, SP5, SP6 | | | 9-12-PS2-A-1 |
| Practice 6.11: Simulating Projectile Motion II | PS2.A.a | SP4, SP5, SP6 | HSA.CED.A.1, HSA.REI.B.3 | | 9-12-PS2-A-1 |

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# Exploring Physics Unit 7: Linear Momentum
## Core Standards§

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| Activity | NGSS Disciplinary Core Ideas (High School) | Science Practices | Math Common Core Standards | Math Practices | MO 2016 |
|---|---|---|---|---|---|
| Exploring Collisions Lab | PS2.A.b | SP2, SP3, SP4, SP5, SP6 | | MP1, MP2 | 9-12-PS2-A-2 |
| Reading Page: Impulse | PS2.A.b | SP4, SP5, SP6 | HSA.CED.A.2 | MP1, MP2 | 9-12-PS2-A-2 |
| Practice 7.1: Impulse | PS2.A.b | SP4, SP5, SP6 | HSN.VM.A.3, HSA.CED.A.1, HSA.REI.B.3 | | 9-12-PS2-A-2 |
| Reading Page: Linear Momentum | PS2.A.b | SP2, SP4, SP5, SP6, SP8 | HSN.Q.A.1, HSA.CED.A.2 | | 9-12-PS2-A-2 |
| Practice 7.2: Calculating Linear Momentum | PS2.A.b | SP4, SP5, SP6 | HSA.CED.A.1 | | 9-12-PS2-A-2 |
| Connecting Impulse and Momentum Lab | PS2.A.b | SP2, SP4, SP5, SP6, SP8 | HSA.CED.A.2 | | 9-12-PS2-A-2 |
| Reading Page: Connecting Impulse and Change in Momentum | PS2.A.b | SP2, SP4, SP5, SP6, SP8 | HSA.CED.A.2 | | 9-12-PS2-A-2 |

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|---|---|---|---|---|---|
| Practice 7.3: Impulse and Change in Momentum | PS2.A.b | SP4, SP5, SP6 | HSA.CED.A.1, HSA.REI.B.3 | MP1, MP2, MP6 | 9-12-PS2-A-2 |
| Elastic and Inelastic Collisions Lab | PS2.A.b | SP2, SP3, SP4, SP5, SP6 | | | 9-12-PS2-A-2 |
| Reading Page: Types of Collisions | PS2.A.b | SP4, SP5, SP6 | HSA.CED.A.2 | | 9-12-PS2-A-2 |
| Momentum in Collisions Lab | PS2.A.b | SP2, SP3, SP4, SP5, SP6 | HSA.CED.A.1 | | 9-12-PS2-A-2 |
| Reading Page: Conservation of Linear Momentum | PS2.A.b | SP2, SP4, SP5, SP6, SP8 | HSA.CED.A.2 | | 9-12-PS2-A-2 |
| Practice 7.4: Applying Conservation of Momentum | PS2.A.b | SP4, SP5, SP6 | HSN.VM.A.3, HSA.CED.A.1, HSA.REI.B.3 | MP1, MP2, MP6 | 9-12-PS2-A-2 |

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## Exploring Physics Unit 8: Energy

## Alignment by Activity with Next Generation Science Standards* Disciplinary Core Ideas and Mathematics Common Core Standards§

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| Activity | NGSS Disciplinary Core Ideas (High School) | Science Practices | Math Common Core Standards | Math Practices | MO 2016 |
|---|---|---|---|---|---|
| Exploring Energy – Lab | PS1.B.a, PS2.A.a, PS2.A.b, PS2.B.a, PS2.B.b, PS3.A.b, PS3.A.c, PS3.B.b, PS3.B.e, PS3.C.a, PS3.D.a | SP2, SP3 | | | 9-12-PS1-B-6, 9-12-PS2-A-1, 9-12-PS2-A-2, 9-12-PS2-A-4, 9-12-PS3-A-1, 9-12-PS3-A-2, 9-12-PS3-B-4. 9-12-PS3-C-5 |
| Reading Page: Energy | PS3.A.a, PS3.B.a, PS3.B.b | | | | 9-12-PS3-A-1 |
| Practice 8.1. Physical systems, states, processes | PS1.B.a, PS2.A.a, PS2.A.b, PS2.B.a, PS2.B.b, PS3.A.b, PS3.A.c, PS3.B.b, PS3.B.e, PS3.C.a, PS3.D.a | SP2, SP3 | | | 9-12-PS2-A-1, 9-12-PS2-A-4, 9-12-PS3-A-1, 9-12-PS3-A-2, 9-12-PS3-B-4. 9-12-PS3-C-5 |
| Reading Page: The Law of Conservation of Energy | PS3.A.a, PS3.B.a, PS3.B.b | | | | 9-12-PS3-A-1 |
| Exploring Energy Transformations Lab | PS2.A.c | SP2, SP3, SP6 | | | 9-12-PS3-A-2 |
| Reading Page: Using Pie Charts to Represent Energy Storage and Transformations | PS3.A.a, PS3.B.a, PS3.D.a | SP2, SP5, SP6 | HSA.SSE.B.3 | MP2 | 9-12-PS3-A-1, 9-12-PS3-A-2, 9-12-PS3-B-4. |
| Practice 8.2. Energy Pie Charts | PS3.A.a, PS3.B.a, PS3.D.a | SP2, SP5, SP6 | HSA.SSE.B.3 | MP2 | 9-12-PS3-A-1, 9-12-PS3-A-2, 9-12-PS3-B-4. |

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|---|---|---|---|---|---|
| Exploring Energy Transfers Lab | PS2.A.c | SP2, SP3, SP6 | | | 9-12-PS2-A-2, 9-12-PS3-A-1 |
| Reading Page: Using Energy Bar Graphs to Represent Energy Transfers | PS3.A.a, PS3.B.a, PS3.D.a | SP2, SP5, SP6 | HSA.SSE.B.3 | MP2 | 9-12-PS3-A-1 |
| Practice 8.3. Energy Bar Graphs | PS3.A.a, PS3.B.a, PS3.D.a | SP2, SP5, SP6 | HSA.SSE.B.3 | MP2 | 9-12-PS3-A-1, 9-12-PS3-A-3 |
| What is Work? Lab | | SP1, SP2, SP3, SP4, SP5, SP6 | HSN.Q.A.1, HSA.CED.A.2, HSA.REI.B.3, HSF.IF.B.6, HSS.ID.B.6, HSS.ID.C.7 | MP1, MP2, MP4, MP6 | |
| Reading Page: Work  and Energy | | | HSN.Q.A.1 | | |
| Practice 8.4. Calculating Work | | SP4, SP5 | HSA.CED.A.1 | MP1, MP2, MP6 | |
| Relating Work to Change in Energy Conceptual Lab | | SP5 | HSA.SSE.A.1, HSA.CED.A.1, HSA.REI.B.3 | MP1, MP2, MP6 | |
| Reading Page: Gravitational Potential Energy | PS3.B.c | SP5 | HSN.Q.A.1 | | 9-12-PS3-A-1 |
| Practice 8.5. Gravitational Potential Energy | PS3.B.c | SP2, SP5 | | MP2 | 9-12-PS3-A-1 |
| How much energy is stored in a spring?  Elastic Potential Energy Lab | PS3.B.c | SP1, SP3, SP4, SP5, SP6 | HSA.CED.A.1, HSA.CED.A.2, HSA.REI.B.3, HSF.IF.B.4, HSF.IF.B.6, HSS.ID.B.6, HSS.ID.C.7 | MP2, MP4 | 9-12-PS3-A-1 |
| Reading Page: Elastic Potential Energy | PS3.B.c | | HSA.SSE.A.1.a, HSA.CED.A.2, HSA.REI.A.1 | | 9-12-PS3-A-1 |

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| Practice 8.6. Energy in Springs | PS3.B.c | SP2, SP4, SP5 | HSA.CED.A.1, HSA.REI.A.1, HSF.IF.B.4, HSS.ID.B.6 | MP1, MP2, MP6 | 9-12-PS3-A-1 |
| How much energy do we have when moving? Kinetic Energy Lab | PS3.B.c | SP2, SP3, SP4, SP5, SP6 | HSN.Q.A.1, HSA.SSE.A.1, HSA.SSE.A.1.a, HSA.CED.A.2, HSA.REI.A.1, HSF.IF.B.4, HSF.IF.B.6, HSS.ID.B.6, HSS.ID.B.6.c, HSS.ID.C.7 | MP4 | 9-12-PS3-A-1 |
| Reading Page: Kinetic Energy | PS3.B.c | | HSN.Q.A.1, HSA.CED.A.2 | | 9-12-PS3-A-1 |
| Practice 8.7. Kinetic Energy | PS3.B.c | | HSN.VM.A.3, HSA.CED.A.1, HSF.IF.B.4, HSS.ID.B.6 | MP1, MP2, MP6 | 9-12-PS3-A-1 |
| Practice 8.8. Conservation of Energy Problems | PS3.B.c | SP2 | HSN.VM.A.3, HSA.CED.A.1 | MP1, MP2, MP6 | 9-12-PS3-A-1 |
| Human Power Lab | | SP3, SP4, SP5, SP6 | HSN.Q.A.1, HSA.SSE.A.1, HSA.CED.A.1 | MP2, MP4 | |
| Reading Page: Power | | | HSN.Q.A.1, HSA.SSE.A.1, HSA.CED.A.2 | | |
| Practice 8.9. Power | | | HSA.CED.A.1 | MP2 | |

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**Comparison of High School Physical Science NGSS and Missouri Science Standards**

prepared by Meera Chandrasekhar and Dorina Kosztin, Department of Physics and Astronomy, University of Missouri, Columbia Mo, July

| **NGSS Performance Expectations** | **NGSS DCIs** | **Missouri Learning Standards GLEs Spring 2016** |
|---|---|---|
| | **PS2 - Motion and Stability: Forces and Interactions** | |
| | **PS2.A: Forces and Motion** | **A. Forces and Motion** |
| HS-PS2-1. Analyze data to support the claim that Newton’s second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration. | a. Newton’s second law accurately predicts changes in the motion of macroscopic objects. | 9-12-PS2 -1 Analyze data to support and verify the concepts expressed by Newton's 2nd law of motion, as it describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration. [Clarification Statement: Examples of data could include tables or graphs of position or velocity as a function of time for objects subject to a net unbalanced force, such as a falling object, an object rolling down a ramp, or a moving object being pulled by a constant force.] |
| HS-PS2-2. Use mathematical representations to support the claim that the total momentum of a system of objects is conserved when there is no net force on the system. | | |
| HS-PS2-3. Apply scientific and engineering ideas to design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision. | b. Momentum is defined for a particular frame of reference; it is the mass times the velocity of the object. | 9-12-PS2-2 Use mathematical representations to support and verify the concepts that the total momentum of a system of objects is conserved when there is no net force on the system. [Clarification Statement: Emphasis is on the quantitative conservation of momentum in interactions and the qualitative meaning of this principle.] |
| HS-PS2-4. Use mathematical representations of Newton’s Law of Gravitation and Coulomb’s Law to describe and predict the gravitational and electrostatic forces between objects. | | |

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| HS-PS2-5. Plan and conduct an investigation to provide evidence that an electric current can produce a magnetic field and that a changing magnetic field can produce an electric current. | c. If a system interacts with objects outside itself, the total momentum of the system can change; however, any such change is balanced by changes in the momentum of objects outside the system. | 9-12-PS2-3 Apply scientific principles of motion and momentum to design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision. [Clarification Statement: Examples of evaluation and refinement could include determining the success of the device at protecting an object from damage and modifying the design to improve it. Examples of a device could include a football helmet or a parachute.] |
| HS-PS2-6. Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.* | | |
| | **PS2.B. Types of Interactions** | **B. Types of Interactions** |
| | a. Newton's law of universal gravitation and Coulomb's law provide the mathematical | 9-12-PS2 -4 Use mathematical representations of Newton's Law of Gravitation to describe and predict |
| | b. Forces at a distance are explained by fields (gravitational, electric, and magnetic) permeating space that can transfer energy through space. Magnets or electric currents cause magnetic fields; electric charges or changing magnetic fields cause electric fields. | 9-12-PS2-5 Plan and conduct an investigation to provide evidence that an electric current can produce a magnetic field and that a changing magnetic field can produce an electric current. |
| | **PS3. Energy** | |
| | **PS3.A Definitions of Energy** | **A. Definitions of Energy** |
| HS-PS3-1. Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known. | a. Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. That there is a single quantity called energy is due to the fact that a system's total energy is conserved, even as, within the system, energy is continually transferred from one object to another and between its various possible forms. | 9-12-PS3- 1 Create a computational model to calculate the change in the energy of one component in a system when the changes in energy are known. [Clarification Statement: Emphasis is on explaining the meaning of mathematical expressions used in the model.] |
| HS-PS3-2. Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motions of particles (objects) and energy associated with the relative position of particles (objects). | | |

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| HS-PS3-3. Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.* | b. At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy. | |
| HS-PS3-4. Plan and conduct an investigation to provide evidence that the transfer of thermal energy when two components of different temperature are combined within a closed system results in a more uniform energy distribution among the components in the system (second law of thermodynamics). | c. These relationships are better understood at the microscopic scale, at which all of the different manifestations of energy can be modeled as a combination of energy associated with the motion of particles and energy associated with the configuration (relative position of the particles). In some cases the relative position energy can be thought of as stored in fields (which mediate interactions between particles). This last concept includes radiation, a phenomenon in which energy stored in fields moves across space. | 9-12-PS3- 2 Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motions of particles (objects) and energy associated with the relative position of particles (objects). [Clarification Statement: Examples of phenomena at the macroscopic scale could include the conversion of kinetic energy to thermal energy, the energy stored due to position of an object above the earth, and the energy stored between two electrically-charged plates. Examples of models could include diagrams, drawings, descriptions, and computer simulations.] |
| HS-PS3-5. Develop and use a model of two objects interacting through electric or magnetic fields to illustrate the forces between objects and the changes in energy of the objects due to the interaction. | d. “Electrical energy” may mean energy stored in a battery or energy transmitted by electric currents. | |
| | **PS3.B Conservation of Energy and Energy Transfer** | **B. Conservation of Energy and Energy Transfer** |
| | a. Conservation of energy means that the total change of energy in any system is always equal to the total energy transferred into or out of the system. | 9-12-PS3- 1 Create a computational model to calculate the change in the energy of one component in a system when the changes in energy are known. [Clarification Statement: Emphasis is on explaining the meaning of mathematical expressions used in the model.] |
| | b. Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems. | |

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| | c. Mathematical expressions, which quantify how the stored energy in a system depends on its configuration (e.g. relative positions of charged particles, compression of a spring) and how kinetic energy depends on mass and speed, allow the concept of conservation of energy to be used to predict and describe system behavior. | |
| | d. The availability of energy limits what can occur in any system. | |
| | e. Uncontrolled systems always evolve toward more stable states—that is, toward more uniform energy distribution (e.g., water flows downhill, objects hotter than surrounding environment cool down). | |
| | **PS3.C Relationships Between Energy and Forces** | **C. Relationships Between Energy and Forces** |
| | a. When two objects interacting through a field change relative position, the energy stored in the field is changed. | 9-12-PS3 - 5 Develop and use a model of two objects interacting through electric or magnetic fields to illustrate the forces between objects and the changes in energy of the objects due to the interaction. . [Clarification Statement: Examples of models could include drawings, diagrams, and texts, such as drawings of what happens when two charges of opposite polarity are near each other.] |
| | **PS3.D Energy in Chemical Processes** | **D. Energy in Chemical Process and Everyday Life** |
| | a. Although energy cannot be destroyed, it can be converted to less useful forms—for example, to thermal energy in the surrounding environment. | |
| | b. Solar cells are human-made devices that likewise capture the sun’s energy and produce electrical energy. | |

| **PS4. Waves and Electromagnetic Radiation** | | |
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| HS-PS4-1. Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media. | **PS4.A Wave Properties** | **A. Wave Properties** |
| HS-PS4-2. Evaluate questions about the advantages of using a digital transmission and storage of information. | a. The wavelength and frequency of a wave are related to one another by the speed of travel of the wave, which depends on the type of wave and the medium through which it is passing. | 9-12-PS4-1 Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media. [Clarification Statement: Examples of data could include electromagnetic radiation traveling in a vacuum and glass, sound waves traveling through air and water, and seismic waves traveling through the Earth.] |
| HS-PS4-3. Evaluate the claims, evidence, and reasoning behind the idea that electromagnetic radiation can be described either by a wave model or a particle model, and that for some situations one model is more useful than the other. | | |
| HS-PS4-4. Evaluate the validity and reliability of claims in published materials of the effects that different frequencies of electromagnetic radiation have when absorbed by matter. | b. Information can be digitized (e.g., a picture stored as the values of an array of pixels); in this form, it can be stored reliably in computer memory and sent over long distances as a series of wave pulses. | |
| HS-PS4-5. Communicate technical information about how some technological devices use the principles of wave behaviorand wave interactions with matter to transmit and capture information and energy. | c. Waves can add or cancel one another as they cross, depending on their relative phase (i.e., relative position of peaks and troughs of the waves), but they emerge unaffected by each other. (Boundary: The discussion at this grade level is qualitative only; it can be based on the fact that two different sounds can pass a location in different directions without getting mixed up.) | 9-12-PS4-2 Evaluate the claims, evidence, and reasoning behind the idea that electromagnetic radiation can be described either by a wave model or a particle model, and that for some situations one model is more useful than the other. [Clarification Statement: Emphasis is on how the experimental evidence supports the claim and how a theory is generally modified in light of new evidence. Examples of a phenomenon could include resonance, interference, diffraction, and photoelectric effect.] |
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| | **PS4.B: Electromagnetic Radiation** | **B. Electromagnetic Radiation** |
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| | a. Electromagnetic radiation (e.g., radio, microwaves, light) can be modeled as a wave of changing electric and magnetic fields or as particles called photons. The wave model is useful for explaining many features of electromagnetic radiation, and the particle model explains other features. | 9-12-PS4-3 Communicate technical information about how electromagnetic radiation interacts with matter. [Clarification Statement: Examples could include solar cells capturing light and converting it to electricity; medical imaging; and communications technology.] |
| | b. When light or longer wavelength electromagnetic radiation is absorbed in matter, it is generally converted into thermal energy (heat). Shorter wavelength electromagnetic radiation (ultraviolet, X-rays, gamma rays) can ionize atoms and cause damage to living cells. | 9-12-PS4 -4 Evaluate the validity and reliability of claims in published materials of the effects that different frequencies of electromagnetic radiation have when absorbed by matter. [Clarification Statement: Emphasis is on the idea that photons associated with different frequencies of light have different energies, and the damage to living tissue from electromagnetic radiation depends on the energy of the radiation. Examples of published materials could include trade books, magazines, web resources, videos, and other passages that may reflect bias.] |
| | c. Photoelectric materials emit electrons when they absorb light of a high-enough frequency. | |

| | **PS4.C: Information Technologies and Instrumentation** | |
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| | a. Multiple technologies based on the understanding of waves and their interactions with matter are part of everyday experiences in the modern world (e.g., medical imaging, communications, scanners) and in scientific research. They are essential tools for producing, transmitting, and capturing signals and for storing and interpreting the information contained in them. | |

**Additional standards in Missouri Learning Standards that are not explicitly addressed in NGSS DCIs.**

9-12-PS3 -3 Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy. [Clarification Statement: Emphasis is on both qualitative and quantitative evaluations of devices. Examples of devices could include Rube Goldberg devices, wind turbines, solar cells, solar ovens, and generators. Examples of constraints could include use of renewable energy forms and efficiency.]

9-12-PS3 -4 Plan and conduct an investigation to provide evidence that the transfer of thermal energy when two components of different temperature are combined within a closed system results in a more uniform energy distribution among the components in the system (second law of thermodynamics). [Clarification Statement: Emphasis is on analyzing data from student investigations and using mathematical thinking to describe the energy changes both quantitatively and conceptually. Examples of investigations could include mixing liquids at different initial temperatures or adding objects at different temperatures to water.]