Milford Public Schools Curriculum

Department: Science
Course Name: High School Physics
Course Description:
In this course, students will investigate the relationships between physical events that they observe and the fundamental underlying forces that cause them. In the first half of the course, using hands-on investigations, students build an understanding of forces and interactions and Newton's Second Law. Students also develop understanding that the total momentum of a system of objects is conserved when there is no net force on the system. Students will be able to use Newton's Law of Gravitation to describe and predict the gravitational forces between objects.

During the second half of the year, through the study of waves and their interactions with matter, students develop understandings around how many technologies work. Students are able to apply understanding of how wave properties and the interactions of electromagnetic radiation with matter can transfer information across long distances, store information, and investigate nature on many scales. Students will also demonstrate their understanding of engineering ideas by learning about how technological devices use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy. Finally, students will identify kinds of electric charges, explore the interactions of charged objects, and describe electric fields.

UNIT 1 : Basics of Motion	
Unit Description: Students will describe and solve problems involving one and two dimensional motion. Creating various graphs of motion will enable students to analyze and/or predict the motion of objects in the world around them.	
LEARNING GOALS	
Enduring Understanding: Newton's Laws can be used to describe and predict the motion of objects.	**Essential Question:** How do we know that something is moving and how do we describe its motion?

Content and Skills:

Students will know and be able to:

1. Distinguish between distance and displacement using examples.
2. Define and calculate speed as the distance traveled divided by the elapsed time.
3. Define and calculate velocity as the change in position divided by the elapsed time.
4. Define and calculate acceleration as the change in velocity divided by the elapsed time.
5. Develop a model to explain the difference between and relationships among speed, velocity, and acceleration.
6. Investigate and make a claim about the straight line motion of an object in different situations (e.g., constant velocity, constant acceleration)
7. Create and interpret displacement-time graphs, velocity-time graphs, and acceleration-time graphs in order to translate between different representations of the motion of objects (verbal/written descriptions, motion diagrams, data tables, and graphical representations).
8. Solve problems utilizing the equations of motion with constant acceleration in order to accurately describe the one-dimensional and two-dimensional motion of an object.

9. Determine components of a vector and combine vectors providing justification using graphical representations and verbal explanations.
10. Investigate the time of impact of a dropped ball as compared with the time of impact for a ball rolled off a cliff of the same height in order to determine which ball reaches the ground first and provide justification for the determination.
11. Calculate where an object will land when launched under different conditions (for example, a ball rolling off a cliff, a ball launched at an angle) and providing justification for the calculation using mathematical expressions and graphical analysis.

Standards Addressed:

Next Generation Science Standards (NGSS):
Disciplinary Core Idea Standards:
PS2.A: Forces and Motion- Newton's second law accurately predicts changes in the motion of macroscopic objects. (HS-PS2-1)

Science and Engineering Practices:
Planning and Carrying out investigations
Analyzing and interpreting data
Using Mathematics and Computational Thinking

Crosscutting Concepts:
Patterns
Cause and Effect

UNIT 2: Forces and Motion

Unit Description:
Students will explore the interrelationship of mass, force and acceleration through their understanding of Newton's three Laws. Learning how to construct proper free body diagrams allows students to analyze problems involving forces. Throughout the unit, students will conduct investigations and experiments in order to explore how Newton's Laws apply to their daily life.

LEARNING GOALS

Enduring Understanding(s):	Essential Question(s):
A net force causes a change in motion of an object either by contact or at a distance. Unbalanced forces cause acceleration.	What causes a change in motion for everyday objects? How can gravity be pulling the moon towards the Earth and yet the moon does not hit?

Content and Skills:

Students will know and be able to:
1. Describe the relationship between the inertia of an object and the mass of the object.
2. Explain how seatbelts counteract inertia to reduce injuries in car crashes.

3. Analyze the causes of whiplash (in terms of inertia) in rear-end collisions and how headrests reduce injuries.
4. Compare and contrast different types of contact forces.
5. Compare and contrast different types of field forces.
6. Create free body diagrams to relate the forces acting on an object or system with the net force acting on the object or system.
7. Describe the relationship between acceleration, mass and force providing justification using verbal descriptions and mathematical expressions.
8. Develop models to explain Newton's Third Law of Motion using force-pairs.
9. Apply understandings of forces to determine the gravitational force between two masses.
10. Analyze data to describe how the gravitational force between two objects is affected as mass and/or distance changes.
11. Compare the relationship between mass and weight on different planets as a function of gravitational force.
12. 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. (NGSS HS-PS2-1)

Standards Addressed:

Next Generation Science Standards (NGSS):

Disciplinary Core Idea Standards:

PS2.A: Forces and Motion- Newton's Second Law accurately predicts changes in the motion of macroscopic objects. (HS-PS2-1) Momentum is defined for a particular frame of reference; it is the mass times the velocity of the object. (HS-PS2-2) 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.

Science and Engineering Practices:

Planning and Carrying out investigations
Analyzing and interpreting data
Using Mathematics and Computational Thinking
Constructing Explanations

Crosscutting Concepts:

Systems and System Models
Cause and Effect

UNIT 3: Work and Energy
Unit Description: Students will explore the interrelationship between work and energy. Through the application of the work-energy equation, students will be able to analyze the energy of a system. Learning how to construct proper force-displacement graphs allows students to analyze work performed.

LEARNING GOALS	
Enduring Understanding(s): Energy can be transformed from one form into another, but the total amount of energy remains constant.	**Essential Question(s):** How is energy transferred and conserved? How does a roller coaster system transform work and energy?

Content and Skills:

Students will know and be able to:

1. Define energy in terms of work.
2. Calculate work (W = Fd) and illustrate that simple machines do not decrease work, rather, they decrease application force by increasing the distance that the force is applied.
3. Analyze the amount of work done when lifting and lowering various weights in different scenarios.
4. Define and calculate kinetic energy (KE = (1/2)mv2), and gravitational potential energy (PE = mgh).
5. Apply mathematical expressions to describe potential energy and kinetic energy of objects.
6. Explain how kinetic energy depends upon mass and speed.
7. Explain and apply the law of conservation of energy to real world problems.
8. Predict, using mathematical expressions, changing energy quantities in a system.
9. Define and calculate mechanical energy as the sum of the kinetic and potential energy.
10. Analyze the total mechanical energy of a system (e.g., an ideal roller coaster system) at several points using the law of conservation of energy.
11. Analyze the total mechanical energy of a roller coaster system with losses.
12. Create force-displacement graphs and use them to determine work done.
13. Using examples, distinguish between the work done and the power used.
14. Give examples of how work done changes the energy of an object.
15. Examine how mechanical energy can be converted into electrical energy.
16. 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. (HS-PS3-1)
17. 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 objects and energy associated with the relative positions of objects. (HS-PS3-2)
18. Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy. (HS-PS3-3)

Standards Addressed:

Next Generation Science Standards (NGSS):
Disciplinary Core Idea Standards:
PS3.A: Definitions of Energy
PS3.B: Conservation of Energy and Energy Transfer

Science and Engineering Practices:
Developing and Using Models
Planning and Carrying Out Investigations
Analyzing and Interpreting Data
Designing Solutions and Constructing Explanations
Using Mathematics and Computational Thinking

Crosscutting Concepts:
Energy and Matter
Systems and System Models
Cause and Effect

UNIT 4: Momentum and Collisions	
Unit Description: Students will apply the law of conservation of momentum to a system of interacting objects. Students will analyze elastic and inelastic collisions and relate them to real world examples. Students will examine safety features that are used to reduce impact force experienced during collisions.	
LEARNING GOALS	
Enduring Understanding(s): Momentum can be transferred from one object to another, but the total amount of momentum remains constant in a closed system.	**Essential Question(s):** What happens when things collide? Why do crumple zones in cars reduce injuries? Why can't a person push a car while sitting in it?

Content and Skills:

Students will know and be able to:

1. Calculate the momentum of a moving object.
2. Define and calculate impulse ($F\Delta t$) and apply it in the relationship, $F\Delta t = m\Delta v$.
3. Determine the total momentum of a system of objects.
4. 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-PS2-2)
5. Analyze a car crash using the law of conservation of momentum.
6. State the law of conservation of momentum and use it to solve one -dimensional explosion and collision problems using the equation, $m1v1+m2v2 = m1v1'+m2v2'$.
7. Create a force-time graph in order to model forces in a system.
8. Investigate and describe how impact time relates to force experienced during a collision.
9. Compare and contrast how airbags and seat belts reduce injuries in a collision and evaluate factors that impact their effectiveness.
10. Define and identify situations involving elastic and inelastic collisions and explosions.
11. Apply scientific and engineering ideas to design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision. (HS-PS2-3)

Standards Addressed:

Next Generation Science Standards:

Disciplinary Core Idea Standards:
PS2.A: Forces and Motion- Momentum is defined for a particular frame of reference; it is the mass times the velocity of the object. (HS-PS2-2) 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.

Science and Engineering Practices:
Developing and Using Models
Planning and Carrying out investigations
Analyzing and interpreting data

Using Mathematics and Computational Thinking
Designing Solutions

Crosscutting Concepts:
Energy and Matter
Scale, Proportion, and Quantity
Systems and System Models

UNIT 5: Waves

Unit Description:
In this unit, students will explore the properties and characteristics of mechanical waves. Students will study sound waves in order to develop understandings around basic wave characteristics and properties. Students will identify and/or calculate features of a waveform. Students will predict wave patterns when two pulses interfere.

LEARNING GOALS

Enduring Understanding(s):	Essential Question(s):
A wave is a traveling disturbance that transports energy but not matter. Some waves require a medium for transportation.	How do waves transfer energy? How and why do we hear each other when we speak?

Content and Skills:

Students will know and be able to:

1. Describe the motion of the wave and of the wave medium for transverse and longitudinal waves.
2. Distinguish between transverse and longitudinal waves.
3. Describe a wave in terms of wavelength, frequency, amplitude, speed and period.
4. Solve problems using the wave equation ($v = f\lambda$).
5. Examine how and explain why wave speed varies in different media.
6. Sketch and describe how wavefronts reflect off of plane and concave barriers.
7. Sketch and describe how wavefronts refract when crossing a boundary, how the change in wave speed at the boundary produces refraction, and how refraction is affected by the wavelength of the wave.
8. Develop a model to describe reflection, refraction, and transmission of waves at an interface between two media.
9. Sketch and describe how wavefronts can be diffracted and explain how diffraction varies with wavelength.
10. Investigate and describe the simple harmonic motion of a pendulum.
11. Investigate and describe the factor that affects the period of a pendulum.
12. Explain simple harmonic motion in terms of a pictorial representation of a wave.
13. Sketch and describe how the crests and troughs of two transverse waves can interfere (add or subtract) while passing through one another, and produce a pattern by two in-phase point sources.
14. Analyze data to create a model to explain constructive and destructive interference of waves.

15. Illustrate that the wavelength of an approaching or receding wave source is different from the wavelength of a stationary wave source (i.e., explain the Doppler Effect).
16. Provide examples how humans combine waves in order to encode and transmit information.
17. Investigate and describe how the phenomenon of resonance is used in speech and musical instrument design
18. Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media. (HS-PS4-1)

Standards Addressed:

Next Generation Science Standards (NGSS):
Disciplinary Core Idea Standards:
PS4.A Wave Properties-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. (HS-PS4-1)

Waves can be used to transmit information and energy.

Science and Engineering Practices:
Developing and Using Models
Planning and Carrying out investigations
Analyzing and interpreting data
Using Mathematics and Computational Thinking

Crosscutting Concepts:
Patterns
Cause and Effect
Scale, Proportion, and Quantity
Energy and Matter

UNIT 6: Electromagnetic Waves	
Unit Description: Students will study electromagnetic waves, specifically light waves, and how they differ from mechanical waves. Through their understandings of light waves, students will explore how different technologies and devices are designed based upon the application of knowledge of the properties of waves.	
LEARNING GOALS	
Enduring Understanding(s): A wave is a traveling disturbance that transports energy but not matter. An electromagnetic wave is a wave of changing magnetic and electric fields and does not require a medium.	**Essential Question(s):** How are electromagnetic waves used to transfer energy and send and store information?

Content and Skills:

Students will know and be able to:

1. Define and provide examples of the various types of electromagnetic waves.
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. (HS-PS4-3)
3. Compare the frequency and energy of the seven basic waves in the electromagnetic spectrum.
4. Recognize that light is the visible portion of the range of electromagnetic frequencies.
5. Investigate and describe the differences between the characteristics and properties of sound waves and radio waves, and other waves on the EM spectrum.
6. Conduct investigations to determine the relationship between wavelength and frequency of EM waves.
7. Evaluate the validity and reliability of claims in published materials of the effects that different frequencies of electromagnetic radiation have when absorbed by matter. (HS-PS4-4)
8. Describe practical uses for each of the seven basic waves in the electromagnetic spectrum.
9. Sketch and describe how light waves reflect off of plane and concave barriers.
10. Sketch and describe how light waves refract when crossing a boundary, how the change in wave speed at the boundary produces refraction, and how refraction is affected by the wavelength of the wave.
11. Sketch and describe how light waves are diffracted when traveling through small apertures, and explain how diffraction varies with wavelength.
12. Develop models to explain various ways how electromagnetic radiation interacts with matter
13. Explain, using examples, how many modern technologies (i.e., sonar, scanners, ultrasound, x-rays, telescopes, lasers) rely on the manipulation of electromagnetic waves
14. Describe how knowledge of the properties of various types of waves is used to design communication and information systems (i.e., mobile phones, semiconductors, computer chips, wireless computer networks).
15. Evaluate questions about the advantages of using a digital transmission and storage of information. (HS-PS4-2)

16. Communicate technical information about how some technological devices use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy. (HS-PS4-5)

Standards Addressed:

Next Generation Science Standards (NGSS):

Disciplinary Core Idea Standards:
PS4.A: Wave Properties: The wavelength and frequency of a wave are related to one another by the speed of the wave, which depends on the type of wave and the medium through which it is passing. Waves can be used to transmit information and energy.

PS4.B: Electromagnetic Radiation: 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. (HS-PS4-3)
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. (HS-PS4-4)
Photoelectric materials emit electrons when they absorb light of a high-enough frequency. (HS-PS4-5)

PS4.C: Information Technologies and Instrumentation: 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. (HS-PS4-5)

Science and Engineering Practices:
Developing and Using Models
Planning and Carrying out investigations
Engaging in Argument from Evidence
Obtaining, Evaluating, and Communicating Information

Crosscutting Concepts:
Systems and System Models
Cause and Effect

UNIT 7: Interaction of Charged Particles

Unit Description:
Students will analyze the interactions of charged particles and how charge interacts with matter. Students will examine the differences between electrical forces and gravitational forces.

LEARNING GOALS

Enduring Understanding(s):	**Essential Question(s):**
The flow of charged particles can be used to transform between electrical energy and other forms of energy.	What makes electrical charge flow? Why does a lightbulb turn on when you flip the switch?

Content and Skills:

Students will know and be able to:

1. Explain that charged objects exert forces that can be repulsive or attractive.
2. Describe how the electrical force between two charges is affected as charge and/or distance changes.
3. Calculate the magnitude and direction of the force on a charge due to another charge.
4. Calculate the magnitude of electrical force arising between two charged bodies using Coulomb's Law
5. Use mathematical representations of Coulomb's Law to describe and predict the electrostatic forces between objects. (HS-PS2-4)
6. Evaluate the combined effect of gravitational force and electrical force between two particles.
7. Describe the difference between charging by contact (conduction) and induction.
8. Evaluate the final charge distribution when two charged objects come in contact.
9. Distinguish between electric force and electric fields.
10. Compare and contrast magnetic fields with electrical fields.
11. 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. (HS-PS2-5)

Standards Addressed:

Next Generation Science Standards (NGSS):
Disciplinary Core Idea Standards:
PS2.B Types of Interactions: Forces at a distance are explained by fields that can transfer energy and can be described in terms of the arrangement and properties of the interacting objects and the distance between them. These forces can be used to describe the relationship between electrical and magnetic fields.

PS3.A Definitions of energy

PS3.C Relationship between energy and forces: Fields contain energy that depends on the arrangement of the objects in the field.

Science and Engineering Practices:

Developing and Using Models
Planning and Carrying out Investigations
Engaging in Argument from Evidence
Obtaining, Evaluating, and Communicating Information

Crosscutting Concepts:
Energy and Matter