2016 MA STE MS-HS *Physical*

Please direct comments, suggested edits,
The standards and strand maps are a
(*) denotes integration of technolo
NOTE: There is not an implied sequence from Intro
possible after middle school and e

Grade 6

Grade 7

Science Strand Map (April 2016)

, and questions to: mathsciencetech@doe.mass.edu.
vailable at: www.doe.mass.edu/stem/review.html
gy/engineering through a practice or core idea.
ductory Physics to Chemistry; the dotted line indicates either are
ach can be taken without having taken the other.

Grade 8

Introductory Physics (Grade 9-10)

Chemistry (Grade 10-11)

Math: A-CED A.2, B.3; 7.RP.1,2,3

HS-PS1-7. Use mathematical representations and provide experimental evidence to support the claim that atoms, and therefore mass, are conserved during a chemical reaction. Use the mole concept and proportional relationships to evaluate the quantities (masses or moles) of specific reactants needed in order to obtain a specific amount of product. Clarification Statements: Mathematical representations include balanced chemical equations that represent the laws of conservation of mass and constant composition (definite proportions),mass-to-mass stoichiometry, and calculations of percent yield. Evaluations may involve mass-to-mass stoichiometry and atom economy comparisons, but only for single-step reactions that do not involve complexes.

HS-PS1-5. Construct an explanation based on kinetic molecular theory for why varying conditions influences the rate of a chemical reaction or a dissolving process. Design and test ways to slow down or accelerate rates of processes (chemical reactions or dissolving) by altering various conditions.*
Clarification Statements: Explanations should be based on three variables in collision theory: (a) quantity of collisions per unit time, (b) molecular orientation on collision, and (c) energy input needed to induce atomic rearrangements. Conditions that affect these three variables include temperature, pressure, concentrations of reactants, agitation, particle size, surface area, and addition of a catalyst. State Assessment Boundary: State assessment will be limited to simple reactions in which there are only two reactants and to specifying the change in only one variable at a time.

1: Matter & Its Interactions

Math: MA 6-RP 3e; 7-RP.2

6.MS-PS1-7(MA). Use a particulate model of matter to explain that density is the amount of matter (mass) in a

4-PS3-1

5

8.MS-PS1-4. Develop a m
changes in particle motio
temperature, and state o
energy is added or rem
Emphasis is on qualita
solids, liquids, and gases
thermal energy increase
the particles until a chan
models could include dr
of pure substances
dioxi

Mat

8.MS-PS1-1. Develop a m
combine in a multitude of
which make up all of the liv
encounter; (b) atoms forn
range in size from two t
mixtures are composed o
substances. Clarificat
molecular-level models
dimensional ball and s
representations showing di
types of atoms. State As
electrons and bonding ene
of complex structures, con
atoms in a complex mol
calculations of pro
not expected

5-PS1-4

Math: 6.SP.B.4

8.MS-PS1-2. Analyze and
of substances before and
determine if a chem
Clarification Statements: E
burning sugar or steel wool,
and mixing zinc with HC
density, melting po
flamm

-PS1-1

Math: 7-SP.2

odel that describes and predicts on, relative spatial arrangement, f a pure substance when thermal noved. Clarification Statements: tive molecular-level models of to show that adding or removing es or decreases kinetic energy of nge of state occurs. Examples of awings and diagrams. Examples could include water, carbon de, and helium.

h: 7-RP.3

odel to describe that: (a) atoms ways to produce pure substances ving and nonliving things that we n molecules and compounds that o thousands of atoms; and (c) f different proportions of pure ion Statement: Examples of could include drawings, three tick structures, or computer ifferent molecules with different sessment Boundary: Valence rgy, the ionic nature of subunits nplete depictions of all individual ecule or extended structure, or portions in mixtures are in state assessment.

HS-ESS1-1

d interpret data on the properties d after the substances interact to nical reaction has occurred. Examples of reactions could include fat reacting with sodium hydroxide, . Properties of substances include: int, boiling point, solubility, ability, and odor.

HS-PS1-6. Design ways to control the extent of a reaction at equilibrium (relative amount of products to reactants) by altering various conditions using Le Chatelier's principle. Make arguments based on kinetic molecular theory to account for how altering conditions would affect the forward and reverse rates of the reaction until a new equilibrium is established.* Clarification Statements: Conditions that can be altered to affect the extent of a reaction include temperature, pressure, and concentrations of reactants. Conditions that can be altered to affect the rates of a reaction include temperature, pressure, concentrations of reactants, agitation, particle size, surface area, and addition of a catalyst. State Assessment Boundaries: Calculations of equilibrium constants or concentrations are not expected in state assessment. State assessment is limited to simple reactions in which there are only two reactants and to specifying the change in only one variable at a time.

Math: 6-NS 5.

HS-PS1-1. Use the periodic table as a model to predict the relative properties of main group elements, including ionization energy and relative sizes of atoms and ions, based on the patterns of electrons in the outermost energy level of each element. Use the patterns of valence electron configurations, core charge, and Coulomb's law to explain and predict general trends in ionization energies, relative sizes of atoms and ions, and reactivity of pure elements. Clarification Statement: Size of ions should be relevant only for predicting strength of ionic bonding. State Assessment Boundary: State assessment is limited to main group (s and p block) elements.

HS-PS1-3. Cite evidence to relate physical properties of substances at the bulk scale to spatial arrangements, movement, and strength of electrostatic forces among ions, small molecules, or regions of large molecules in the substances. Make arguments to account for how compositional and structural differences in molecules result in different types of intermolecular or intramolecular interactions. Clarification Statements: Substances include both pure substances in solid, liquid, gas and networked forms (such as graphite). Examples of bulk properties of substances to compare include melting point and boiling point, density, and vapor pressure. Types of intermolecular interactions include dipole-dipole (including hydrogen bonding), ion-dipole, and dispersion forces. State Assessment Boundary: Calculations of vapor pressure by Raoult's law,

given volume. Apply proportional reasoning to describe, calculate, and compare relative densities of different materials.

HS-ESS1-5

8.MS-ESS2-5

8.MS-ESS2-1

6.MS-PS1-8(MA). Conduct an experiment to show that many materials are mixtures of pure substances that can be separated into their component pure substances. Clarification Statement: Examples of common mixtures include salt water, oil and vinegar, milk, concrete, and air.

4-PS3-2

Math: 5.G.A.2

6.MS-PS1-6. Plan and conduct an experiment involving exothermic and endothermic chemical reactions to measure and describe the release of thermal energy. Clarification Statements: Emphasis is on describing transfer of energy to an from the environment. Examples of chemical reactions could include dissolving ammonium chloride or calcium chloride.

5-PS1-2

8.MS-PS1-5. Use a mo
rearranged during a
molecules with new p
present in the reactan
and thus the total
Clarification State
include physical mo
forms, that represent a
Use of atomic mass
symbolic equatio
not expec

8.MS-ETS2-5(MA)

del to explain that substances are
a chemical reaction to form new
roperties. Explain that the atoms
ts are all present in the products
number of atoms is conserved.
ment: Examples of models can
dels or drawings, including digital
toms. State Assessment Boundary:
es, molecular weights, balancing
ns, or intermolecular forces is
ted in state assessment.

8. MS-LS1-7

properties of heterogeneous mixtures, names and bonding angles in molecular geometries are not expected in state assessment.

ELA: WHST.9-10.1

HS-PS1-11 (MA). Design strategies to identify and separate components of a mixture based on relevant chemical and physical properties. Clarification Statements: Emphasis is on compositional and structural features of components of the mixture. Strategies can include chromatography, distillation, centrifuging, and precipitation reactions. Relevant chemical and physical properties can include melting point, boiling point, conductivity, and density.

HS-PS1-2. Use the periodic table model to predict and design simple combination reactions that result in two main classes of binary compounds, ionic and molecular. Develop an explanation based on given observational data and the electronegativity model about the relative strengths of ionic or covalent bonds. Clarification Statements: Simple combination reactions include synthesis (combination), decomposition, single displacement, double displacement, and combustion. Predictions of reactants and products can be represented using Lewis dot structures, chemical formulas, or physical models. Observational data include that binary ionic substances (i.e., substances that have ionic bonds), when pure, are crystalline salts at room temperature (common examples include NaCl, KI, Fe2O3); and substances that are liquids and gases at room temperature are usually made of molecules that have covalent bonds (common examples include CO2, N2, CH6,H2O, C8h18).

HS-PS1-10(MA). Use an oxidation-reduction reaction model to predict products of reactions given the reactants, and to communicate the reaction models using a representation that shows electron transfer (redox). Use oxidation numbers to account for how electrons are redistributed in redox processes used in devices that generate electricity or systems that prevent corrosion.* Clarification Statements: Reactions are limited to simple oxidation-reduction that do not require hydronium or hydroxide ions to balance half reactions.

HS-PS1-8. Develop a model to illustrate the energy released or absorbed during the processes of fission, fusion, and radioactive decay. Clarification Statements:

HS-PS1-4. Develop a model to illustrate the energy

2: Motion and Stability: Forces

3-PS2-3

7.MS-PS2-5. Use scientific evidence to argue that fields exist between objects with mass, between magnetic objects, and between electrically charged objects that exert force on each other even though the objects are not in contact. State Assessment Boundary: State assessment is limited to gravitational, electric and magnetic fields. Calculations of force are not expected in state assessment.

3-PS2-1

8.MS-PS2-2. Provide evide[...] motion depends on the sum [...] force) and the mass of th[...] Emphasis is on balanced (N[...] forces in a system, qualitati[...] changes in motion (Newto[...]

Examples of models include simple quantitative models, such as pictures or diagrams. Types of radioactive decay include alpha, beta, and gamma.

HS-ESS1-1

HS-PS2-4. Use mathematical representations of Newton’s law of gravitation and Coulomb’s law to both qualitatively and quantitatively describe and predict the effects of gravitational and electrostatic forces between objects. Clarification Statement: Emphasis is on relative changes when distance, mass or charge, or both are changed. State Assessment Boundaries: State assessment will be limited to systems with two objects Permittivity of free space is not expected in state assessment.

Math: A-CED.4; A-REI.3

HS-PS2-9(MA). Evaluate simple series and parallel circuits. to predict changes to voltage, current or resistance when simple changes are made to a circuit. Clarification Statements: Predictions of changes can be represented numerically, graphically, or algebraically using a Ohm's law. Simple changes to a circuit may include adding a component, changing the resistance of a load of a component, and adding a parallel path in circuits with batteries and common loads. Simple circuits can be represented in schematic diagrams. State Assessment Boundary: Use of measurement devices and predictions of changes in power are not expected in state assessment.

Math: 6.EE.5, C.9; 6.RP.A.3b; 8.EE.B.5; A-CED.4; A.F.LE.1b,c

HS-PS2-1. Analyze data to support the claim that Newton’s second law of motion is a mathematical model describing change in motion (the acceleration) of objects when acted on by a net force. Clarification Statements: 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, and a moving object being pulled by a constant force. Forces can include contact forces, including friction, and forces acting at a distance, such as gravity and magnetic forces. State Assessment Boundary: Variable forces are not expected in state assessment.

Math: 6.NS.C.5; 7.EE.B.3

...ence that the change in an object’s ... of the forces on the object (the net ... e object. Clarification Statement: ... Newton’s first law) and unbalanced ... ve comparisons of forces, mass and ... n’s second law) in one dimension.

transferred during an exothermic or endothermic chemical reaction based on the bond energy difference between bonds broken (absorption of energy) and bonds formed (release of energy). Clarification Statement: Examples of models may include molecular-level drawings and diagrams of reactions or graphs showing the relative energies of reactants and products. State Assessment Boundary: Calculations using Hess's law are not expected in state assessment.

HS-PS1-9(MA). Relate the strength of an aqueous acidic or basic solution to the extent of an acid or base reacting with water measured by the hydronium ion concentration (pH) of the solution. Make arguments about the relative strengths of two acids or bases with similar structure and/or composition. Clarification Statements: Reactions are limited to Arrhenius and Bronsted-Lowry acid-base reaction patterns with monoprotic acids. Comparisons of relative strengths of aqueous acid or base solutions made from similar acid or base substances is limited to arguments based on periodic properties of elements, the electronegativity model of electron distribution, empirical dipole moments, and molecular geometry. Acid or base strength comparisons are limited to homologous series and should include dilution and evaporation of water.

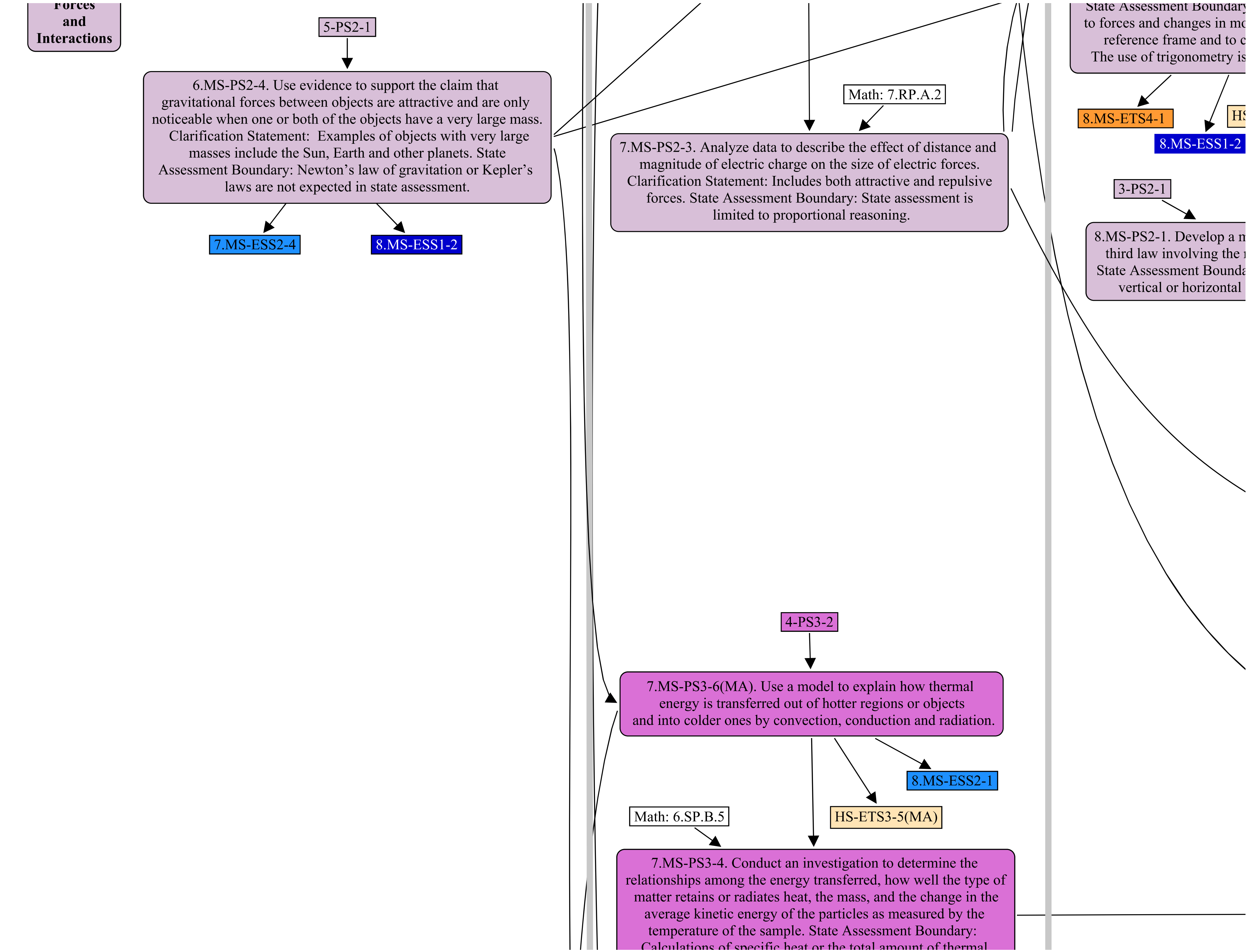
HS-PS2-7(MA). Construct a model to explain how ions dissolve in polar solvents (particularly water). Analyze and compare solubility and conductivity data to determine the extent to which different ionic species dissolve. Clarification Statement: Data for comparison should include different concentrations of solutions with the same ionic species, and similar ionic species dissolved in the same amount of water.

Math:A-CED 2, 4; A-REI.3

HS-PS2-8(MA). Use kinetic-molecular theory to compare the strengths of electrostatic forces and the prevalence of interactions that occur between molecules in solids, liquids, and gases.. Use the combined gas law to determine changes in pressure, volume, and temperature.

MS-ETS2-2 (MA)

HS-PS2-6. Communicate scientific and technical information ...


Forces and Interactions
5-PS2-1
6.MS-PS2-4. Use evidence to support the claim that gravitational forces between objects are attractive and are only noticeable when one or both of the objects have a very large mass. Clarification Statement: Examples of objects with very large masses include the Sun, Earth and other planets. State Assessment Boundary: Newton's law of gravitation or Kepler's laws are not expected in state assessment.
7.MS-ESS2-4
8.MS-ESS1-2
Math: 7.RP.A.2
7.MS-PS2-3. Analyze data to describe the effect of distance and magnitude of electric charge on the size of electric forces. Clarification Statement: Includes both attractive and repulsive forces. State Assessment Boundary: State assessment is limited to proportional reasoning.
4-PS3-2
7.MS-PS3-6(MA). Use a model to explain how thermal energy is transferred out of hotter regions or objects and into colder ones by convection, conduction and radiation.
8.MS-ESS2-1
HS-ETS3-5(MA)
Math: 6.SP.B.5
7.MS-PS3-4. Conduct an investigation to determine the relationships among the energy transferred, how well the type of matter retains or radiates heat, the mass, and the change in the average kinetic energy of the particles as measured by the temperature of the sample. State Assessment Boundary:
8.MS-ETS4-1
8.MS-ESS1-2
3-PS2-1

y: State assessment will be limited
otion in one dimension in an inertial
change in one variable at a time.
s not expected in state assessment.

S-ETS3-6(MA)

HS-ETS3-3(MA)

Math: 6.NS.C.5

nodel that demonstrates Newton's
motion of two colliding objects.
ary: State assessment is limited to
interactions in one dimension.

HS-PS2-2. Use mathematical representations to show that the total momentum of a system of interacting objects is conserved when there is no net force on the system. Clarification Statement: Emphasis is on qualitative meaning of the conservation of momentum and the quantitative understanding of the conservation of linear momentum in interactions involving elastic and inelastic collisions between two objects in one dimension.

Math: N-VM.1,3

HS-PS2-10(MA). Use free-body force diagrams and algebraic expressions representing Newton's laws of motion to predict changes to velocity, and acceleration for an object moving in one dimension in various situations. Clarification Statements: Predictions of changes in motion can be made numerically, graphically, and algebraically using basic equations for velocity, constant acceleration, and Newton's first and second laws. Forces can include contact forces, including friction, and forces acting at a distance, such as gravity and magnetic forces.

HS-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: Both qualitative evaluations and algebraic manipulations may be used.

HS-PS2-5. Provide evidence that an electric current can produce a magnetic field and that a changing magnetic field can produce an electric current. Clarification Statement: Examples of evidence can include movement of a magnetic compass when placed in the vicinity of a current-carrying wire, a magnet passing through a coil that turns on the light of a Faraday flashlight. State Assessment Boundary: Explanations of motors or generators are not expected in state assessment.

HS-PS3-5. Develop and use a model of electric or magnetic fields to illustrate the forces and changes in energy between two magnetically or electrically charged objects changing relative positions in a magnetic or electric field. Clarification Statements: Emphasis is on the change in force and energy as objects move relative to each other. 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.

Math: A-CED.2, 4; A-REI.B.3

about the molecular-level structures of polymers, ionic compounds, acids and bases, and metals to justify why these are useful in the functioning of designed materials.* Clarification Statement: Examples could include comparing molecules with simple molecular geometries, analyzing how pharmaceuticals are designed to interact with sepcific recpetors and considering why electrically conductive materials are often made of metal, household cleaning products often contain ionic compounds to make materials soluable in water or materials that need to be flexible but durable are made up of polymers. State Assessment Boundary: State assessment will be limited to comparing substances of the same type with one compositional or structural feature different.

ELA: WHST.9-10.9

HS-PS3-4.b. Provide evidence from informational text or available data to illustrate that the transfer of energy during a chemical reaction in a closed system involves changes in energy dispersal (enthalpy change) and heat content(entropy change) while assuming the overall energy in the system is conserved. State Assessment Boundary: Calculations involving Gibbs

3:
Energy

Calculations of specific heat or the total amount of thermal energy transferred are not expected in state assessment.

7.MS-ETS1-4

8.MS-ESS2-5

7.MS-PS3-3. Apply scientific principles of energy and heat transfer to design, construct, and test a device to minimize or maximize thermal energy transfer.* Clarification Statement: Examples of devices could include an insulated box, a solar cooker, and a Styrofoam cup State Assessment Boundary: Accounting for specific heat or calculations of the total amount of thermal energy transferred is not expected in state assessment.

7.MS-PS3-2. Develop a model to describe the relationship between the relative positions of objects interacting at a distance and their relative potential energy in the system. Clarification Statement: Examples of objects within systems interacting at varying distances could include Earth and either a roller coaster cart at varying positions on a hill or objects at varying heights on shelves, changing the direction/orientation of a magnet, and a balloon with static electrical charge being brought closer to a sream of water. Examples of models could include representations, diagrams, pictures, and written descriptions of systems. State Assessment Boundary: State assessment will be limited electric, magnetic, and gravitational interactions of two objects at a time. Calculations of potential energy are not expected in state assessment.

4-PS3-1

Math: 7.RP.A.2

7.MS-PS3-1. Construct and interpret data and graphs to describe the relationships among kinetic energy, mass, and speed of an object. Clarification Statements: Examples could include riding a bicycle at different speeds and rolling different-sized rocks downhill. Consider relationships between kinetic energy vs. mass and kinetic energy vs. speed separate from each other; emphasis is on the difference between the linear and exponential relationships. State Assessment Boundary: Calculation or manipulation of the formula for kinetic energy is not expected in state assessment.

HS-ETS4-5

4-PS3-3

ELA: WHST.6-8.1

7.MS-PS3-5. Present evidence to support the claim that when the motion energy of an object changes, energy is free energy are not expected in state assessment.

HS-PS3-2. Develop and use a model to illustrate that energy at the macroscopic scale can be accounted for as either motions of particles and objects or energy stored in fields. Clarification Statements: Examples of phenomena at the macroscopic scale could include evaporation and condensation the conversion of kinetic energy to thermal energy, the gravitational potential energy stored due to position of an object above the earth, and the stored energy (electric potential) of a charged object's position within an electric field. Examples of models could include diagrams, drawings, descriptions, and computer simulations.

4-PS3-4

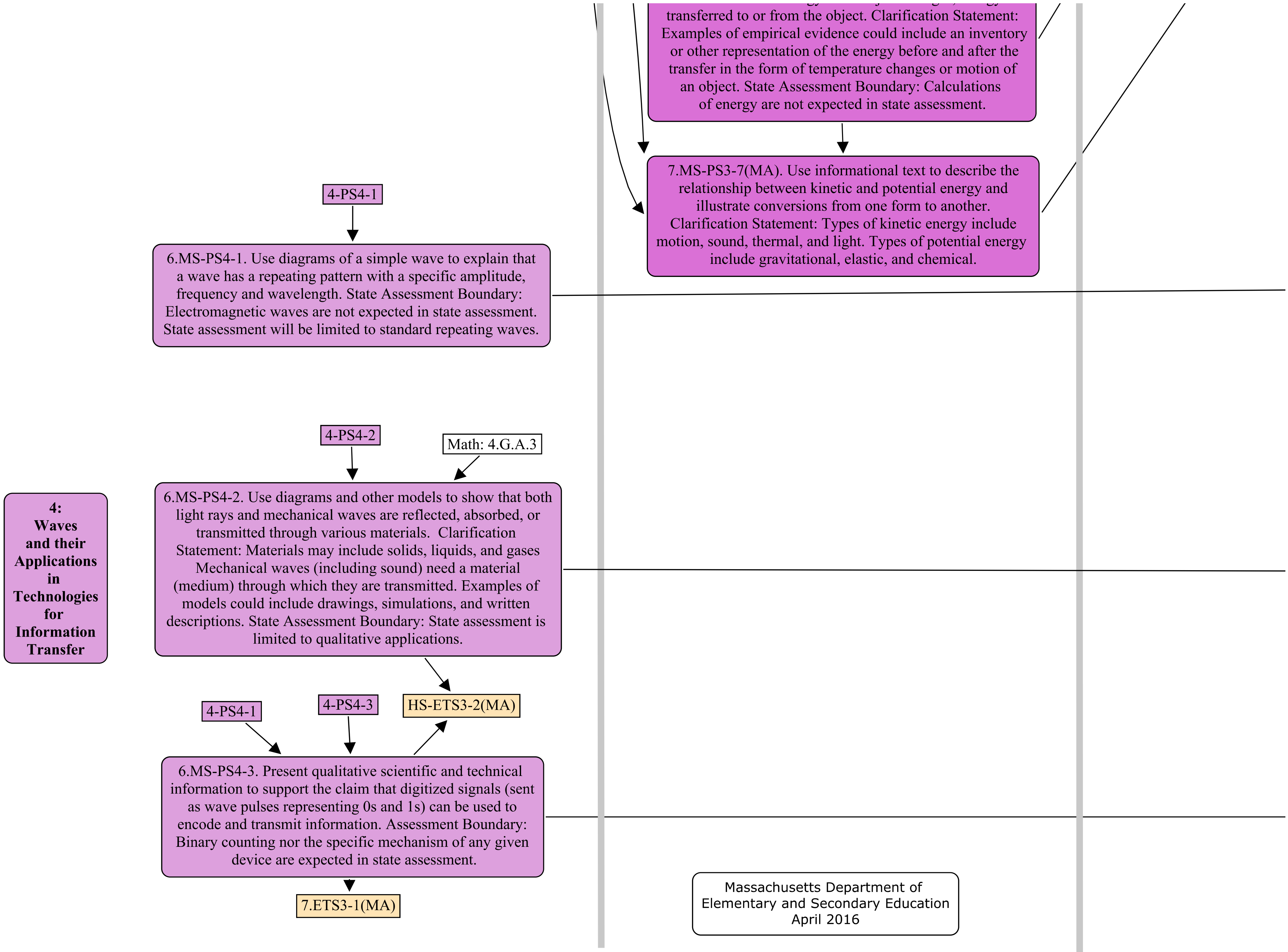
HS-PS3-3. Design and evaluate a device that works within given constraints to convert one form of energy into another form of energy.* Clarification Statements: Emphasis is on both qualitative and quantitative evaluations of devices. Examples of devices could include Rube Goldberg devices, wind turbines, solar cells, solar ovens, and generators. Examples of constraints could include use of renewable energy forms and efficiency. State Assessment Boundary: Quantitative evaluations will be limited to total output for a given input in state assessment.

Math: 8.EE.2

HS-PS3-1. Use algebraic expressions and the principle of energy conservation to calculate the change in energy of one component of a system when the change in energy of the other component(s) of the system, as well as the total energy of the system including any energy entering or leaving the system, is known. Identify any transformations from one form of energy to another, including thermal, kinetic, gravitational, magnetic, or electrical energy, in the system. Clarification Statement: Systems should be limited to two or three components, and to thermal energy, kinetic energy, or the energies in gravitational, magnetic, or electric fields.

Math: A-CED.4; A.REI.3

HS-PS3-4.a. Provide evidence that when two objects of different temperature are in thermal contact within a closed system, the transfer of thermal energy from higher-temperature objects to lower-temperature objects results in thermal equilibrium, or a more uniform energy distribution among the objects and that temperature changes necessary to achieve thermal equilibrium depend on the specific heat values of the two substances. Clarification Statement: Energy


transferred to or from the object. Clarification Statement: Examples of empirical evidence could include an inventory or other representation of the energy before and after the transfer in the form of temperature changes or motion of an object. State Assessment Boundary: Calculations of energy are not expected in state assessment.
7.MS-PS3-7(MA). Use informational text to describe the relationship between kinetic and potential energy and illustrate conversions from one form to another. Clarification Statement: Types of kinetic energy include motion, sound, thermal, and light. Types of potential energy include gravitational, elastic, and chemical.
4-PS4-1
6.MS-PS4-1. Use diagrams of a simple wave to explain that a wave has a repeating pattern with a specific amplitude, frequency and wavelength. State Assessment Boundary: Electromagnetic waves are not expected in state assessment. State assessment will be limited to standard repeating waves.
4-PS4-2
Math: 4.G.A.3
4: Waves and their Applications in Technologies for Information Transfer
6.MS-PS4-2. Use diagrams and other models to show that both light rays and mechanical waves are reflected, absorbed, or transmitted through various materials. Clarification Statement: Materials may include solids, liquids, and gases Mechanical waves (including sound) need a material (medium) through which they are transmitted. Examples of models could include drawings, simulations, and written descriptions. State Assessment Boundary: State assessment is limited to qualitative applications.
4-PS4-1
4-PS4-3
HS-ETS3-2(MA)
6.MS-PS4-3. Present qualitative scientific and technical information to support the claim that digitized signals (sent as wave pulses representing 0s and 1s) can be used to encode and transmit information. Assessment Boundary: Binary counting nor the specific mechanism of any given device are expected in state assessment.
7.ETS3-1(MA)
Massachusetts Department of Elementary and Secondary Education April 2016

changes should be described both quantitatively in a single phase ($Q = mc\Delta T$) and conceptually either in a single phase or during a phase change.

Math: A-CED.2, 4; A-REI.B.3

HS-PS4-1. Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling within various media. Recognize that electromagnetic waves can travel through empty space (without a medium) as comparedto mechanical waves that require a medium. Clarification Statements: Emphasis is on relationships when waves travel within a medium, and comparisons when a wave travels in different media. Examples of situations to consider could include electromagnetic radiation traveling in a vacuum and glass, sound waves traveling through air and water, and seismic waves traveling through the Earth. Relationships include $v = \lambda f$, $T = 1/f$, and the qualitative comparison of the speed of a transverse (including electromagnetic) or longitudinal mechanical wave in a solid, liquid, gas, or vacuum. State Assessment Boundary: Transitions between two media are not expected in state assessment

HS-ESS1-2

HS-PS4-3. Evaluate the claims, evidence, and reasoning behind the idea that electromagnetic radiation can be described by either a wave model or a particle model, and that for some situations involving resonance, interference, diffraction, or the photoelectric effect, one model is more useful than the other. Clarification Statement: Emphasis is on qualitative reasoning and comparisions of the two models. State Assessment Boundary: Calculations of energy levels or resonant frequencies are not is expected in state assessment.

ELA: WHST.9-10.2

HS-PS4-5. 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.* Clarification Statements: Emphasis is on qualitative information and descriptions. Examples of technological devices could include solar cells capturing light and converting it to electricity, medical imaging, and communications technology. Examples of principles of wave behavior include resonance, photoelectric effect, and constructive and destructive interference. State Assessment Boundary: Band theory is not expected in state assessment.