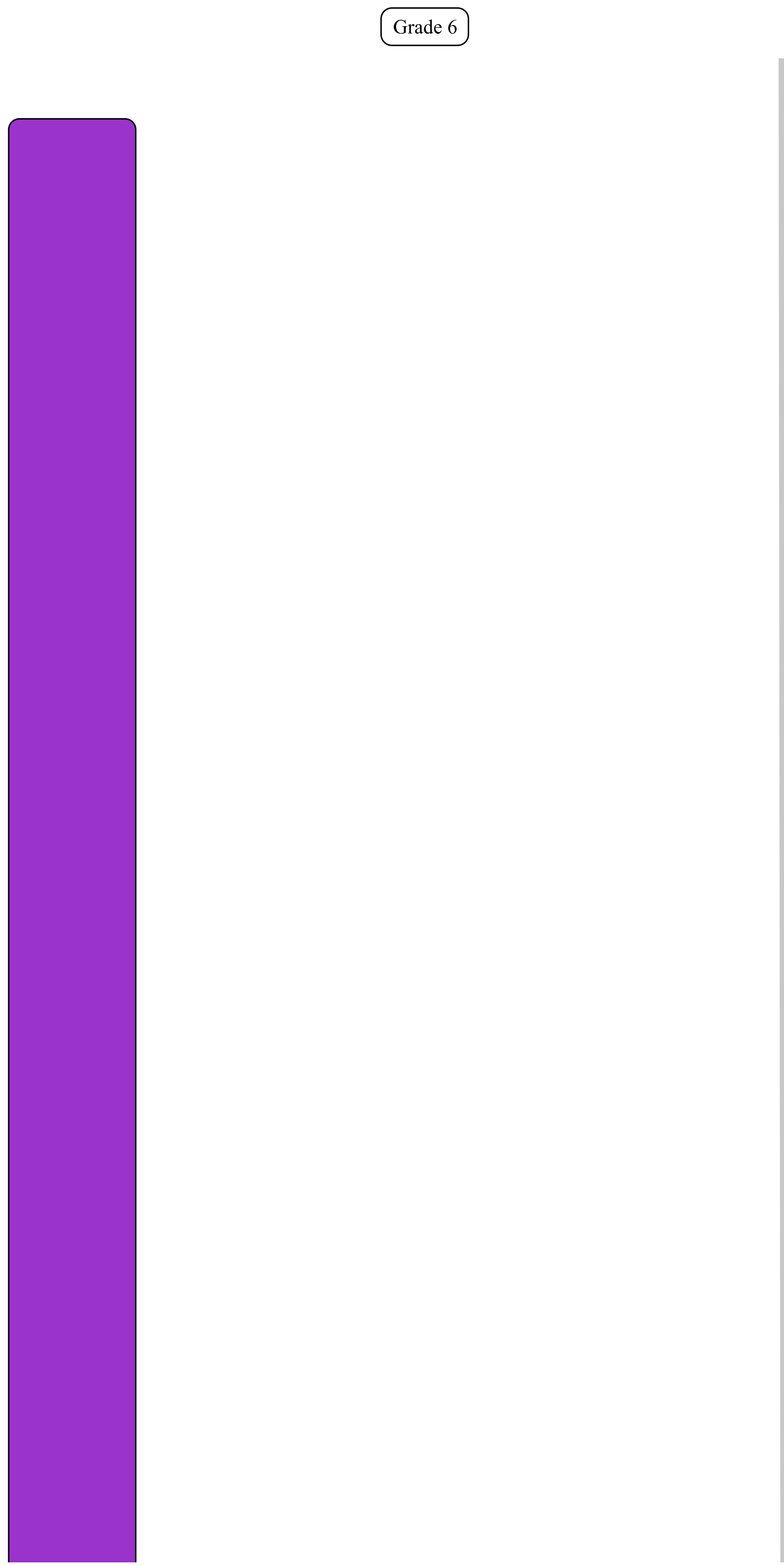
MA Dra



aft Revised MS-HS *Physical Science* Strand Ma

Based on *A Framework for K-12 Science Education* (NRC, 2012) and adapted from the *Next Generation Science Standards* (2013)
Please direct comments, suggested edits, and questions to: mathsciencetech@doe.mass.edu.
The standards and strand maps are available at: www.doe.mass.edu/stem/review.html
(*) denotes integration of technology/engineering through a practice or core idea.
NOTE: There is not an implied sequence from Introductory Physics to Chemistry; the dotted line indicates either are possible after middle school and each can be taken without having taken the other.

Grade 7

Grade 8

Introductory Physics

ap (1/24/14)

s (Grade 9-10)

Chemistry (Grade 10-11)

Math connections forthcoming

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 predict the quantities (masses or moles) of specific reactants or products. [Clarification Statement: Mathematical representations include balanced chemical equations that represent the laws of conservation of mass and constant composition (definite proportions), percent composition, empirical formulas, mass-to-mass stoichiometry, and calculations of percent yield.] [Assessment Boundary: Calculations 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 collision theory for why varying conditions influence the rate of a chemical reaction or a dissolving process. Design and test ways to alter various conditions to influence (slow down or accelerate) rates of processes (chemical reactions or dissolving) as they occur.* [Clarification Statement: Explanations should be based on three variables in collision theory: quantity of collisions per unit time, molecular orientation on collision, and energy input needed to induce atomic rearrangements. Conditions that affect these three variables include temperature, pressure, concentrations of reactants, mixing, particle size, surface area, and addition of a catalyst.] [Assessment Boundary: 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.]

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 collision theory to account for how altering conditions would affect the forward and reverse rates of the reaction until a new equilibrium is established.* [Clarification Statement: Conditions that can be altered include temperature, pressure, concentrations of reactants, mixing, particle size, surface area, and addition of a catalyst.] [Assessment Boundary: Assessment does not include calculating equilibrium constants or concentrations. 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.]

6-NS 5.

HS-PS1-1. Use the periodic table as a model to predict the relative properties of main group elements, including

1: Matter & Its Interactions

Math: MA 6-RP 3e.

MS-PS1-7 (MA). Use a particulate model of matter to explain that density is the amount of matter (mass) in a given volume. Measure the mass and volume of regular and irregular shaped objects and calculate their density.

HS-ESS1-5

MS-ESS2-5 (gr. 8)

MS-ESS2-1 (gr. 8)

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

4-PS3-1

5-PS1-1

MS-PS1-4. Develop a model that describes and predicts changes in particle motion, relative spatial arrangement, temperature, and state of a pure substance when thermal energy is added or removed. [Clarification Statement: Emphasis is on qualitative molecular-level models of solids, liquids, and gases to show that adding or removing thermal energy increases or decreases kinetic energy of the particles until a change of state occurs. Examples of models could include drawings and diagrams. Examples of pure substances could include water, carbon dioxide, and helium.]

MS-PS1-9 (MA). Present evidence to suport the claims that: a. substances are composed of molecules, compounds or atoms; and b. atoms form molecules or compounds that range in size from two to thousands of atoms.

MS-PS1-1. Develop a model to describe that elements combine in a multitude of ways to produce substances which make up all of the living and nonliving things that we encounter. [Clarification Statement: Examples of molecular-level models could include drawings, 3D ball and stick structures, or computer representations showing different molecules with different types of atoms.] [Assessment Boundary: Assessment does not include valence electrons and bonding energy, discussing the ionic nature of subunits of complex structures, or a complete depiction of all individual atoms in a complex molecule or extended structure.]

Math: 6.SP.B.4

HS-ESS1-3

5-PS1-4

MS-PS1-2. Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred. [Clarification Statement: Examples of reactions could include burning sugar or steel wool, fat reacting with sodium hydroxide, and mixing zinc with HCl. Properties of substances include: density, melting point, boiling point, solubility, flammability, and odor.]

MS-ETS2-5 (MA) (gr. 8)

5-PS1-2

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 and Coulomb's law to explain and predict trends in ionization energies, relative sizes of atoms and ions, and reactivity of pure elements. [Assessment Boundary: 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 intermolecular interactions are determined by atomic composition and molecular geometry, and for how ions or small molecules arrange into two major types of three-dimensional crystal structures: atom/ionic networks or molecular crystals. [Clarification Statement: Substances include both pure substances in solid, liquid, gas and networked forms (such as graphite) as well as solutions. Examples of bulk properties of substances include composition, melting point and boiling point, vapor pressure, and surface tension.] [Assessment Boundary: Assessment does not include Raoult's law calculations of vapor pressure. Properties of heterogeneous mixtures are not assessed. Names of specific intermolecular forces (such as dipole-dipole) are not assessed.]

HS-PS1-11 (MA). Construct an argument to show differences in the atomic composition and molecular geometry of substances that allow for identification, detection, and separation of substances in a mixture. [Clarification Statements: Atomic composition of the atom includes electrostatic attractions and repulsions between the electrons and nucleus and that neutral atoms can have different numbers of neutrons (isotopes).]

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. Account for chemical changes in terms of charge redistribution. [Clarification Statement: Simple combination reactions include synthesis (combination), decomposition, single displacement, double displacement, or combustion.] [Assessment Boundary: Assessment is limited to chemical reactions involving main group (s and p block) elements and combustion reactions.]

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 periodic properties of elements, an electron distribution model and the periodic table model to design substances that could be used in devices that produce electricity via oxidation-reduction reactions.* [Clarification Statements: Devices may include batteries, fuel cells, electrolysis, and corrosion-protection.] [Assessment Boundary: Reactions are limited to simple oxidation-reduction reactions that do not require hydronium or hydroxide ion to balance half-reactions. Electron distribution models are limited to oxidation numbers accounting.]

4-PS3-2

Math: 5.G.A.2

MS-PS1-6. Plan and conduct an experiment using exothermic and endothermic reactions to explain that the type and concentration of the reacting substances affects the amount of thermal energy released or absorbed. [Clarification Statement: Examples of chemical reactions could include dissolving ammonium chloride or calcium chloride.] [Assessment Boundary: Assessment is limited to factors of concentration, time, and change in thermal energy (measured by temperature).]

MS-PS2-5. Use
between object
between elec
each other
[Assessment
and magnetic

5-PS2-1

MS-PS2-4. Use evidence to support the claim that gravitational interactions are attractive and are only

MS-PS1-5. Use a model to explain that substances are rearranged during a chemical reaction to form new molecules with new properties. Explain that the atoms present in the reactants are all present in the products and thus the total number of atoms is conserved. [Clarification Statement: Examples of models can include physical models or drawings, including digital forms, that represent atoms.] [Assessment Boundary: Assessment does not include the use of atomic masses, balancing symbolic equations, or intermolecular forces.]

MS-LS1-7 (gr. 8)

Math connections

HS-PS2-4. Use mathematical re
Law of Gravitation and Coulomb
and quantitatively describe a
gravitational and electrostatic
[Clarification Statement: Emph
when distance, mass or charge, c
as the relative strength comparis
[Assessment Boundary: Assess
with two objects and does not i
space.

3-PS2-3

e scientific evidence to argue that fields exist
ts with mass, between magnetic objects, and
ctrically charged objects that exert force on
even though the objects are not in contact.
Boundary: Assessment is limited to electric
c fields, and limited to qualitative evidence
for the existence of fields.]

7-EE 2.

HS-PS2-9 (MA). Analyze si
electrical components in both s
Use appropriate instruments
across and current through a re
determine the resistance in a
voltage and

Math: 6.NS.C.5
6.EE.A.2
7.EE.B.3

3-PS2-1

MS-PS2-2. Provide evidence that the change in an object's motion depends on the sum of the forces on the object (the net force) and the mass of the object. [Clarification Statement: Emphasis is on balanced (Newton's First Law)

HS-PS2-1. Analyze data to supp
second law of motion is a math
motion and change in motion (a

HS-PS1-12 (MA). Combine period patterns and Coulomb's law with observational data about ionic substances versus molecular substances to develop a predictive model for ionic versus covalent bonding in binary structures. [Clarification Statement: Observational data include: ionic substances (i.e., have ionic bonds), when pure, are crystalline salts at room temperature (common examples include NaCl, Na2CO3, FE2O3); and substances that are liquids and gasses at room temperature are usually made of molecules which have covalent bonds (common examples include CO2, N2, CH4, H2O, C8H18, C12H22O11).]

HS-PS1-4. Develop a model to illustrate the energy 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, graphs showing the relative energies of reactants and products, and representations showing energy is conserved.]

HS-PS1-9 (MA). Recognize that the strength of an aqueous acidic or basic solution is determined by the hydronium ion concentration. Use the Arrhenius and Bronsted-Lowry acid-base reaction models and Le Chatelier's principle to predict whether the pH increases or decreases when conditions are modified. Make argumants about the relative strengths of two acids or bases with similar structure and/or compostion. [Clarification Statements: Modification of conditions includes dilution of or addition or removal of reactants or products by physical or chemical means. 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, electronegativity model of electron distribution, empirical dipole moments, and molecular geometry.] [Assessment Boundary: Reactions are limited to Arrhenius and Bronsted-Lowry acid-base reaction patterns with monoprotic acids. Acid or base strength comparisons are limited to homologous series.]

forthcoming

presentations of Newton's
's Law to both qualitatively
nd predict the effects of
forces between objects.
asis is on relative changes
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on between the two forces.]
ment is limited to systems
nclude permittivity of free
]

MS-PS1-13 (MA). Analyze data of the conductivity of pure water versus different solutions of water with another substance dissolved in it to make a claim about the nature of the molecules of the dissolved substances.

HS-PS2-7 (MA). Construct a model to explain the process by which solutes dissolve in solvents, particularly water, and predict how intermolecular forces affect solubility. [Clarification Statement: Predictions include whether the substance will dissolve based on being polar or nonpolar and ionic or covalent.]

imple arrangements of
eries and parallel circuits.
to measure the voltage
sistor. Use Ohm's Law to
circuit when given the
current.

7-EE 2.

(ALG 1) A-CED 2.

HS-PS2-8 (MA). Communicate a qualitiative explanation based on kinetic-molecular theory for why one variable in the combined gas law changes when another is varied. Using kinetic-molecular theory, explain the behavior of gases and the relationship between pressure and volume (Boyle's law), volume and temperature (Charles's law), and pressure and temperature (Gay-Lussac's law). Use the

ort the claim that Newton's
ematical model describing
cceleration) of objects with

2: Motion and Stability: Forces and Interactions

noticeable when one or both of the objects have a very large mass. [Clarification Statement: Examples of objects with very large masses include the Earth, Sun, and other planets.] [Assessment Boundary: Assessment does not include Newton's Law of Gravitation or Kepler's Laws.]

MS-ESS2-4 (gr. 7)

MS-ESS1-2 (gr. 8)

3-PS2

MS-PS2-3. De
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3: Energy

MS-PS3-6 (MA
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Math: 6.SP.

MS-PS3-4. De
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MS-ETS1-4 (

MS-PS3-3. Ap
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MS-PS3-2. De
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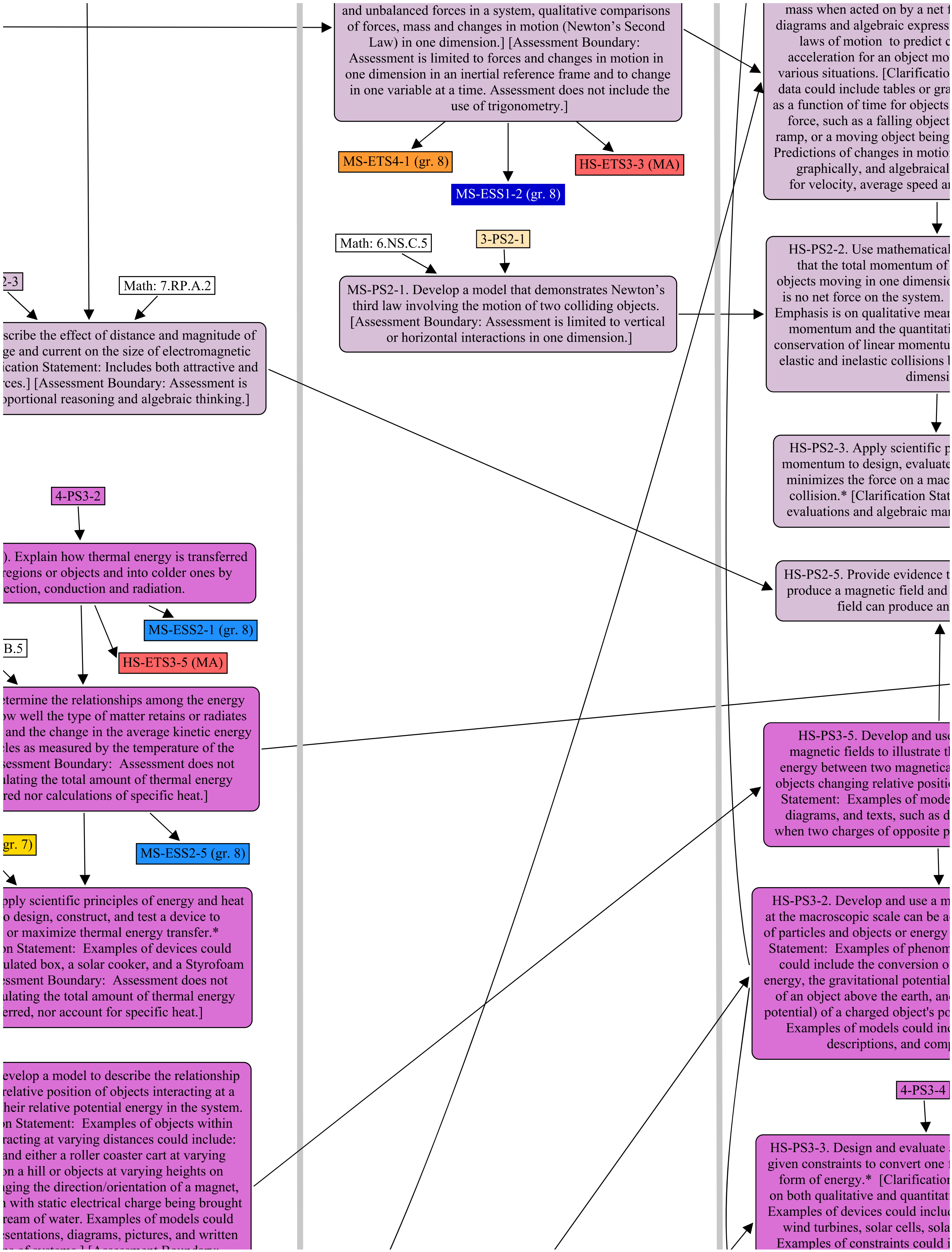
and unbalanced forces in a system, qualitative comparisons of forces, mass and changes in motion (Newton's Second Law) in one dimension.] [Assessment Boundary: Assessment is limited to forces and changes in motion in one dimension in an inertial reference frame and to change in one variable at a time. Assessment does not include the use of trigonometry.]
MS-ETS4-1 (gr. 8)
MS-ESS1-2 (gr. 8)
HS-ETS3-3 (MA)
mass when acted on by a net f
diagrams and algebraic express
laws of motion to predict c
acceleration for an object mo
various situations. [Clarificatio
data could include tables or gra
as a function of time for objects
force, such as a falling object
ramp, or a moving object being
Predictions of changes in motio
graphically, and algebraical
for velocity, average speed a
Math: 6.NS.C.5
3-PS2-1
MS-PS2-1. Develop a model that demonstrates Newton's third law involving the motion of two colliding objects. [Assessment Boundary: Assessment is limited to vertical or horizontal interactions in one dimension.]
HS-PS2-2. Use mathematical
that the total momentum of
objects moving in one dimensio
is no net force on the system.
Emphasis is on qualitative mea
momentum and the quantitati
conservation of linear momentu
elastic and inelastic collisions
dimensi
2-3
Math: 7.RP.A.2
scribe the effect of distance and magnitude of
ge and current on the size of electromagnetic
ication Statement: Includes both attractive and
rces.] [Assessment Boundary: Assessment is
pportional reasoning and algebraic thinking.]
HS-PS2-3. Apply scientific p
momentum to design, evaluate
minimizes the force on a mac
collision.* [Clarification Stat
evaluations and algebraic ma
4-PS3-2
). Explain how thermal energy is transferred
regions or objects and into colder ones by
ection, conduction and radiation.
HS-PS2-5. Provide evidence t
produce a magnetic field and
field can produce a
MS-ESS2-1 (gr. 8)
B.5
HS-ETS3-5 (MA)
etermine the relationships among the energy
ow well the type of matter retains or radiates
and the change in the average kinetic energy
cles as measured by the temperature of the
sessment Boundary: Assessment does not
ulating the total amount of thermal energy
red nor calculations of specific heat.]
HS-PS3-5. Develop and use
magnetic fields to illustrate t
energy between two magnetica
objects changing relative positi
Statement: Examples of mode
diagrams, and texts, such as d
when two charges of opposite p
gr. 7)
MS-ESS2-5 (gr. 8)
pply scientific principles of energy and heat
o design, construct, and test a device to
or maximize thermal energy transfer.*
on Statement: Examples of devices could
ulated box, a solar cooker, and a Styrofoam
essment Boundary: Assessment does not
ulating the total amount of thermal energy
erred, nor account for specific heat.]
HS-PS3-2. Develop and use a m
at the macroscopic scale can be a
of particles and objects or energy
Statement: Examples of phenom
could include the conversion o
energy, the gravitational potential
of an object above the earth, an
potential) of a charged object's p
Examples of models could in
descriptions, and comp
evelop a model to describe the relationship
relative position of objects interacting at a
heir relative potential energy in the system.
on Statement: Examples of objects within
racting at varying distances could include:
and either a roller coaster cart at varying
on a hill or objects at varying heights on
ging the direction/orientation of a magnet,
n with static electrical charge being brought
ream of water. Examples of models could
esentations, diagrams, pictures, and written
4-PS3-4
HS-PS3-3. Design and evaluate
given constraints to convert one
form of energy.* [Clarificatio
on both qualitative and quantitat
Examples of devices could inclu
wind turbines, solar cells, sola
Examples of constraints could i

force. Use free-body force
ions representing Newton's
changes to velocity and
ving in one dimension in
n Statement: Examples of
aphs of position or velocity
subject to a net unbalanced
, an object rolling down a
pulled by a constant force.
n can be made numerically,
ly using basic equations
nd constant acceleration.]

representations to show
a system of interacting
on is conserved when there
[Clarification Statement:
ning of the conservation of
ive understanding of the
m in interactions involving
between two objects in one
on.]

principles of motion and
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tement: Both qualitative
nipulations may be used.]

hat an electric current can
that a changing magnetic
electric current.

a model of electric or
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ons in a field. [Clarification
ls could include drawings,
rawings of what happens
olarity are near each other.]

odel to illustrate that energy
ccounted for as either motions
stored in fields. [Clarification
nena at the macroscopic scale
f kinetic energy to thermal
energy stored due to position
d the energy stored (electric
osition within an electric field.
clude diagrams, drawings,
puter simulations.]

a device that works within
form of energy into another
n Statement: Emphasis is
ive evaluations of devices.
de Rube Goldberg devices,
r ovens, and generators.
nclude use of renewable

combined gas law to determine changes in pressure, volume, and temperature.

MS-ETS2-2 (MA)

HS-PS2-6. Communicate scientific and technical information about the molecular-level structures of different materials to justify why particular classes of substances have specific properties that are useful in the functioning of designed materials.* [Clarification Statement: Examples could include comparing molecules with simple molecular geometries, why electrically conductive materials are often made of metal, foods and household products often contain ionic compounds, materials that need to be flexible but durable are made up of polymers, and pharmaceuticals are designed to interact with specific receptors.] [Assessment Boundary: Assessment is limited to VESPR, polymers, ionic compounds, isomers, and metals.]

HS-PS3-4.b. Provide evidence from literature or available data to illustrate that the transfer of energy within a closed system involves heat (enthalpy change) and rearrangement of the system (entropy change) while the overall energy in the system is conserved.

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MS-PS3-1. C
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4-PS3-3

MS-PS3-5.
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an object.] [A
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MS-PS3-7 (MA
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to another. [Cla
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energy incl

4: Waves and their Applications in Technologies for Information Transfer

4-PS4-1

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. [Assessment Boundary: Assessment does not include electromagnetic waves and is limited to standard repeating waves.]

4-PS4-2

Math: 4.G.A.3

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 gasses. Mechanical waves (including sound) need a material (medium) through which they are transmitted. Examples of models could include drawings, simulations, and written descriptions.] [Assessment Boundary: Assessment is limited to qualitative applications.]

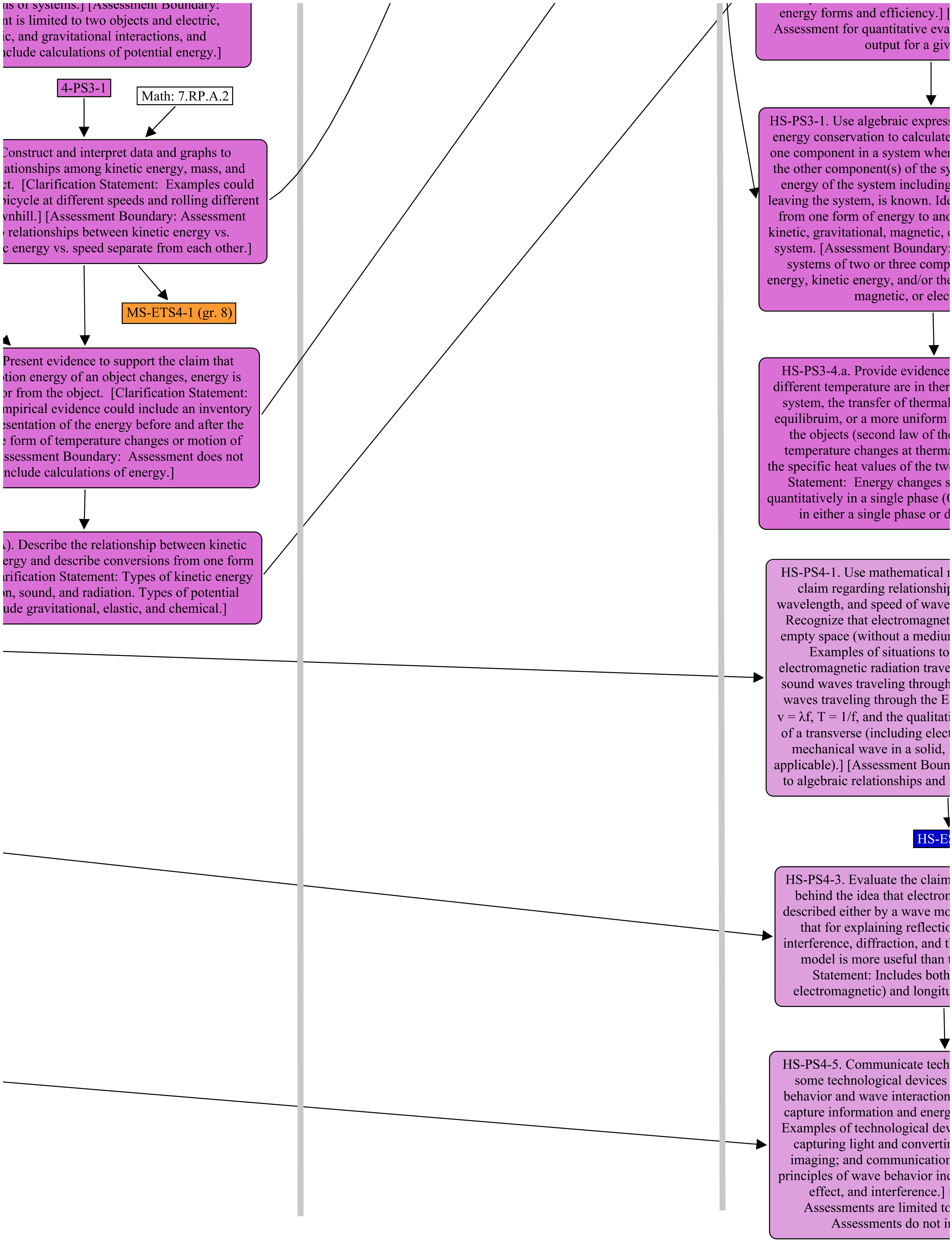
HS-ETS3-2 (MA)

4-PS4-1

4-PS4-3

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: Assessment does not include binary counting nor the specific mechanism of any given device.]

MS-ETS3-1 (gr. 7)


ns of systems.] [Assessment Boundary:
nt is limited to two objects and electric,
ic, and gravitational interactions, and
nclude calculations of potential energy.]
4-PS3-1
Math: 7.RP.A.2
Construct and interpret data and graphs to
ationships among kinetic energy, mass, and
ct. [Clarification Statement: Examples could
bicycle at different speeds and rolling different
wnhill.] [Assessment Boundary: Assessment
o relationships between kinetic energy vs.
c energy vs. speed separate from each other.]
MS-ETS4-1 (gr. 8)
Present evidence to support the claim that
otion energy of an object changes, energy is
or from the object. [Clarification Statement:
mpirical evidence could include an inventory
esentation of the energy before and after the
e form of temperature changes or motion of
ssessment Boundary: Assessment does not
nclude calculations of energy.]
). Describe the relationship between kinetic
ergy and describe conversions from one form
rification Statement: Types of kinetic energy
on, sound, and radiation. Types of potential
ude gravitational, elastic, and chemical.]
energy forms and efficiency.] [
Assessment for quantitative eva
output for a giv
HS-PS3-1. Use algebraic express
energy conservation to calculate
one component in a system wher
the other component(s) of the sy
energy of the system including
leaving the system, is known. Ide
from one form of energy to ano
kinetic, gravitational, magnetic, o
system. [Assessment Boundary:
systems of two or three comp
energy, kinetic energy, and/or the
magnetic, or elec
HS-PS3-4.a. Provide evidence
different temperature are in ther
system, the transfer of thermal
equilibruim, or a more uniform
the objects (second law of the
temperature changes at therma
the specific heat values of the tw
Statement: Energy changes s
quantitatively in a single phase (
in either a single phase or d
HS-PS4-1. Use mathematical r
claim regarding relationship
wavelength, and speed of wave
Recognize that electromagnet
empty space (without a medium
Examples of situations to
electromagnetic radiation trave
sound waves traveling through
waves traveling through the E
v = λf, T = 1/f, and the qualitati
of a transverse (including elect
mechanical wave in a solid,
applicable).] [Assessment Boun
to algebraic relationships and
HS-E
HS-PS4-3. Evaluate the claim
behind the idea that electron
described either by a wave mo
that for explaining reflectio
interference, diffraction, and t
model is more useful than t
Statement: Includes both
electromagnetic) and longitu
HS-PS4-5. Communicate tech
some technological devices
behavior and wave interaction
capture information and energ
Examples of technological dev
capturing light and converti
imaging; and communication
principles of wave behavior inc
effect, and interference.]
Assessments are limited to
Assessments do not i

Assessment Boundary:
luations is limited to total
en input.]

sions and the principle of
the change in energy of
n the change in energy of
ystem, as well as the total
any energy entering or
entify any transformations
other, including thermal,
or electrical energy, in the
Assessment is limited to
onents; and to thermal
e energies in gravitational,
tric fields.]

that when two objects of
mal contact within a closed
energy results in thermal
energy distribution among
ermodynamics) and that
al equilibrium depend on
o substances. [Clarification
hould be descrbied both
Q = mcΔT) and conceptually
luring a phase change.]

representations to support a
ps among the frequency,
s traveling in various media.
ic waves can travel through
n). [Clarification Statement:
consider could include
eling in a vacuum and glass,
air and water, and seismic
arth. Relationships include
ive comparison of the speed
tromagnetic or longitudinal
liquid, gas, or vacuum (if
dary: Assessment is limited
not to include Snell's Law.]

SS1-2

s, evidence, and reasoning
magnetic radiation can be
odel or a particle model, and
on, refraction, resonance,
he photoelectric effect, one
the other. [Clarification
transverse (including
dinal mechanical waves.]

nical information about how
use the principles of wave
s with matter to transmit and
y.* [Clarification Statement:
vices could include solar cells
ng it to electricity; medical
s technology. Examples of
clude resonance, photoelectric
[Assessment Boundary:
qualitative information.
nclude band theory.]