INSPIRED STANDARDS MATCH FOR MONTANA

Standards for Science

Meeting curriculum standards is a major focus in education today. This document highlights the correlation of Inspiration® with the Montana Standards for Science.

The Inspired Standards Match is designed to demonstrate the many ways Inspiration supports the standards and to give educators ideas for using this tool to meet learning goals across the curriculum.

How to read the Inspired Standards Match:

- Pink highlight indicates a standard or objective that is supported by the use of Inspiration
- Green note annotation includes names of an Inspiration template that corresponds to the highlighted standard. These templates are part of the software program and act as starters or frameworks for student work.

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MONTANA STANDARDS FOR SCIENCE

Science is an inquiry process used to investigate natural phenomena, resulting in the formation of theories verified by directed observations. These theories are challengeable and changeable. Data used to support or contradict them must be reproducible.

Although science as a body of knowledge is ever changing, the processes of science are constant. In scientific inquiry, a problem is identified, pertinent data is gathered, hypothesis is formulated, experiments are performed, the results are interpreted, and conclusions are drawn.

Science education strengthens students' basic investigative skills and fosters their understanding of and interest in the world. They acquire and apply critical thinking and problem-solving skills and information critical to survival in a technological society.

The unifying concepts and processes of science are a subject of ideas in science and technology. They provide connections between and among traditional scientific disciplines; are fundamental and comprehensive; are understandable and usable by people who will implement science programs; and can be expressed and experienced in a developmentally appropriate manner during K-12 science education. The unifying concepts and processes are: systems, order, and organization, evidence, models and explanation; constancy, change, and measurement; evolution and equilibrium; and form and function that are woven into the Montana Standards for Science.

Content Standards indicate what all students should know, understand and be able to do in a specific content area.

Benchmarks define our expectations for students' knowledge, skills, and abilities along a developmental continuum in each content area. That continuum is focused at three points—the end of grade 4, the end of grade 8 and grade 12.

Content Standard 1—Students design, conduct, evaluate and communicate scientific investigations.

Content Standard 2—Students demonstrate knowledge of properties, forms, changes and interactions of physical and chemical systems.

Content Standard 3—Students demonstrate knowledge of characteristics, structures and function of living things, the process and diversity of life, and how living organisms interact with each other and their environment.

Content Standard 4—Students demonstrate knowledge of the composition, structures, processes and interactions of Earth's systems and other objects in space.

Content Standard 5—Students understand how scientific knowledge and technological developments impact society.

Content Standard 6—Students understand historical developments in science and technology.

Science Content Standard 1

Students design, conduct, evaluate and communicate scientific investigations.

Rationale

Students must understand the process of science—how information is gathered, evaluated and communicated to others. This process mirrors everyday life. The knowledge and skills related to scientific inquiry enable students to understand how science works and are powerful ways for students to build their understanding of the scientific facts, principles, concepts and applications that are described in the other science standards. In addition, scientific inquiry stimulates student interest, motivation and creativity.

Benchmarks

Students will:

End of Grade 4	End of Grade 8	Upon Graduation—End of Grade 12
1. be given a testable question, plan, design, and safely conduct a scientific investigation with identified variables.	1. identify a question, formulate a hypothesis, control and manipulate variables, devise and safely conduct experiments, predict outcomes and compare and analyze results.	1. identify a testable question, formulate a hypothesis based on prior scientific knowledge, identify dependent and independent variables, safely conduct the experiment, collect and analyze data.
2. select and accurately use appropriate tools to measure (in SI units), process and analyze results of a basic scientific investigation.	2. select and accurately use appropriate equipment and technology to measure (in SI units), gather, process and analyze data from a scientific investigation.	2. select appropriate means for representing, communicating, and defending results of investigations and scientific and technological arguments using appropriate mathematical analysis and graphical representation.
3. represent, communicate and provide supporting evidence of scientific investigations.	3. communicate and defend results of investigations; question results of investigations if different from predicted.	3. question conclusions with insufficient supporting evidence, and recognize that the results of a scientific investigation are always open to revision by further experiments.
4. describe relationships among parts of a familiar system (e.g., digestive system, simple machines) and identify and record changes and patterns of changes in the system.	4. analyze the processes, parts and subsystems of familiar (e.g., electrical circuits, bacteria) and infer cause and effect relationships among components of the system.	4. analyze and apply the concepts of change and equilibrium in a variety of systems (e.g., geochemical systems, global climate).
5. construct models that illustrate simple concepts and compare those models to what they represent.	5. create models to illustrate scientific concepts and use the model to predict change (e.g., computer simulation, a stream table, graphic representation).	5. compare observations of the real world to observations of a constructed model.
6. communicate results from a controlled experiment and are reproducible.	6. distinguish between controlled and uncontrolled experiments by consistency of results.	6. investigate and evaluate science studies and identify strengths and weaknesses in experimental design.

Science Content Standard 2

Students demonstrate knowledge of properties, forms, changes and interactions of physical and chemical systems.

Rationale

Everyone has experience with matter in a variety of forms. Energy is also a central concept in science because all physical interactions involve changes in energy. Therefore, knowledge of the forms of matter and energy is essential to interpreting, explaining, predicting and influencing change in our world.

Benchmarks

Students will:

End of Grade 4	End of Grade 8	Upon Graduation—End of Grade 12
1. examine, describe, compare and classify tangible objects in terms of common physical properties.	1. examine, describe, compare and classify objects and substances based on common physical properties and simple chemical properties.	1. classify and predict chemical and physical properties of matter (electrical charge, current, pH).
2. create mixtures and separate them based on different properties (e.g., salt and sand, iron filings and soil, oil and water).	2. classify, describe, and model matter in terms of elements, compounds, mixtures, atoms and molecules.	2. describe and explain physical interactions of matter using conceptual models (e.g., conservation laws of matter, particle model for gaseous behavior).
3. model and explain that matter exists as solids, liquids and gases and can change from one form to another.	3. model and explain that states of matter, solids, liquids and gases, are dependent upon the quantity of energy present in the system.	3. identify, measure, calculate, and analyze quantitative and qualitative relationships associated with matter and energy transfer or transformation.
4. identify and predict what changes and what remains unchanged when matter experiences an external influence.	4. identify and predict what will change and what will remain unchanged when matter experiences an external force or energy change.	4. describe and predict chemical reactions and physical interaction of matter using words and symbolic equations.
5. identify, build, and describe mechanical systems (e.g., simple and complex machines).	5. identify, build, describe, measure, and analyze mechanical systems (e.g., simple and complex machines).	5. identify the four fundamental forces (gravity, magnetic, weak nuclear force and strong nuclear force) of nature and describe the impact of each on matter.
6. describe the basic characteristics of light, heat, magnetism and sound.	6. define energy and compare and contrast the characteristics of light, heat, motion, magnetism, electricity, sound and mechanical waves.	6. identify, describe, and explain physical and chemical changes involving the conservation of matter and energy and entropy in a closed system.

Science Content Standard 3

Students demonstrate knowledge of characteristics, structures and function of living things, the process and diversity of life, and how living organisms interact with each other and their environment.

Rationale

Students gain a better understanding of the world around them if they study a variety of organisms, microscopic as well as macroscopic. Through the study of similarities and differences of organisms, students learn the importance of classification and the diversity of living organisms. The understanding of diversity helps students understand biological evolution and life's natural processes (cycles, growth and reproduction). Structure, function, body organization, growth and development, health and disease are important aspects to the study of life. The study of living systems provides students important information about how humans critically impact Earth's biomes.

Benchmarks

Students will:

End of Grade 4	End of Grade 8	Upon Graduation—End of Grade 12
1. identify that plants and animals have structures and systems, which serve different functions.	1. compare the structure and function of prokaryotic cells (bacteria) and eukaryotic cells (plant, animal, etc.).	1. investigate and use appropriate technology to demonstrate that all cells have common features as well as differences that determine function and that they are composed of common building blocks (e.g., proteins, carbohydrates, nucleic acids, lipids).
2. identify and describe basic requirements of energy needed and nutritional needs for each human body system.	2. explain how organisms and systems of organisms obtain and use energy resources to maintain stable conditions and how they respond to stimuli (e.g., photosynthesis, respiration).	2. describe and explain the complex processes involved in energy use in cell maintenance, growth, repair and development.
3. develop models that trace the life cycles of different plants and animals and discuss how they differ from species to species.	3. communicate the differences in the reproductive processes of a variety of plants and animals using the principles of genetic modeling (e.g., Punet squares).	3. model the structure of DNA, protein synthesis, and the molecular basis of heredity and how it contributes to the diversity of life.
4. explain cause and effect relationships in living systems and nonliving components within ecosystems.	4. investigate and explain the interdependent nature of biological systems in the environment and how they are affected by human interaction.	4. predict and model the interaction of biotic and abiotic factors, which limit populations (natural selection), and contribute to the change of a species over time (evolution).
5. create and use a classification system to group a variety of plants and animals according to their similarities and differences.	5. use a basic classification scheme to identify local plants and animals.	5. apply a biological classification scheme to infer and discuss the degree of species divergence using local ecosystems.

Science Content Standard 4

Students demonstrate knowledge of the composition, structures, processes and interactions of Earth's systems and other objects in space.

Rationale

By studying Earth, its composition, history and the processes that shape it, students gain a better understanding of the planet on which they live. The world's atmosphere and water are vital to life. Both subtle and wholesale changes in either can have a profound effect on human existence. Knowledge of the Sun and the rest of the Universe help students make predictions about Earth and informed decisions about the future of space exploration.

Benchmarks

Students will:

End of Grade 4	End of Grade 8	Upon Graduation—End of Grade 12
1. describe and give examples of Earth's changing features.	1. model and explain the internal structure of the Earth and describe the formation and composition of Earth's external features in terms of the rock cycle and plate tectonics.	1. use the theory of plate tectonics to explain the inner relationship between earthquakes, volcanoes, and sea floor spreading.
2. describe the physical properties of Earth's basic materials (including soil, rocks, water and gases).	2. differentiate between rocks and classify rocks by how they are formed.	2. identify and classify rocks and minerals based on physical and chemical properties.
3. investigate fossils and make inferences about life and the environment long ago.	3. explain scientific theories about the origin and evolution of the Earth and Solar System by describing how fossils are used as evidence of climatic change over time.	3. relate how evidence from advanced technology, applied to scientific investigations (e.g., large telescopes and space-borne observatories), has dramatically impacted our understanding of the origin, size, and evolution of the Universe.
4. observe and describe local weather and demonstrate how weather conditions are measured.	4. describe the water cycle, the composition and structure of the atmosphere, and the impact of oceans on large scale weather patterns.	4. collect and analyze local, regional, and global weather-related data in order to make inferences and predictions about weather patterns.
5. identify seasons and explain the difference between weather and climate.	5. describe and model the motion and tilt of Earth in relation to the Sun, and explain the concept of day, night, seasons, year.	5. explain the impact of terrestrial, Solar, oceanic, and atmosphere conditions on global climatic patterns.
6. describe objects in the sky and explain that light and heat comes from a star called the Sun.	6. describe the Earth, Moon, planets and other objects in space in terms of size, structure, and movement in relation to the Sun.	6. describe the origin, location, and evolution of stars and their planetary systems in respect to the Solar System, the Milky Way, the Local Galactic Group, and the Universe.

Science Content Standard 5

Students understand how scientific knowledge and technological developments impact society.

Rationale

Our world and human activity is shaped in many ways by the advances in science and technology, which involves the application of science. Because these advances affect all of Earth's living and nonliving systems, it is vital that students understand the interrelationships of science, technology and human activity.

Benchmarks

Students will:

End of Grade 4	End of Grade 8	Upon Graduation—End of Grade 12
1. give examples of how people use science and technology.	1. identify the specific fields of scientific endeavor and related occupations within those fields.	1. identify and describe key factors (technology, competitiveness, world events, etc.) that affect the development and acceptance of scientific thought.
2. model scientific collaboration by sharing and communicating ideas and solutions in a variety of cooperative settings.	2. model collaborative problem solving and give examples of how scientific knowledge is shared, critiqued, and scrutinized by other scientists and the public.	2. model the ongoing, collaborative scientific process of gathering and evaluating information (e.g., assess evidence for and against theories, look for patterns, devise and retest different models).
3. use current scientific knowledge to make inferences and propose solutions for local environmental problems (recycling, waste management).	3. investigate local problems and/or issues and propose solutions or products that address a need, which considers variables (e.g., environmental risks).	3. analyze benefits, limitations, costs, consequences, and ethics involved in using scientific and technological innovations to make reasoned decisions.
4. identify a scientific or technological innovation that benefits the community.	4. apply scientific knowledge and process skills to understand issues and everyday events.	4. give examples of scientific innovation challenging commonly held perceptions.

Science Content Standard 6

Students understand historical developments in science and technology.

Rationale

Students need to understand that scientific knowledge was influenced greatly by societal influences. They also need to know that scientific advances have influenced society. For instance, the development of the atom bomb and the discovery that microbes cause disease, both had a major impact on society. Therefore, the use of history in school science programs is necessary to clarify different aspects of scientific discovery, to understand that scientific knowledge is publicly shared and to understand the role that science has played in the development of various cultures.

Benchmarks

Students will:

End of Grade 4	End of Grade 8	Upon Graduation—End of Grade 12
1. give historical examples of scientific and technological contributions to society.	1. trace developments that demonstrate scientific knowledge is subject to change as new evidence becomes available.	1. give examples of scientific discoveries and describe the interrelationship between technological advances and scientific understanding.
2. describe how scientific inquiry has produced much knowledge about the world.	2. identify major milestones in science that have impacted science, technology and society.	2. analyze and illustrate the historical impact of scientific and technological advances.

Science Performance Standards: A Profile of Four Levels

The Science Performance Standards describe students' knowledge, skills, and abilities in the science content area on a continuum from kindergarten through grade 12. These descriptions provide a picture or profile of student achievement at four performance levels: advanced, proficient, nearing proficiency, and novice.

Advanced:	This level denotes superior performance.
Proficient:	This level denotes solid academic performance for each benchmark. Students reaching this level have demonstrated competency over challenging subject matter, including subject-matter knowledge, application of such knowledge to real-world situations, and analytical skills appropriate to the subject matter.
Nearing Proficiency:	This level denotes that the student has partial mastery or prerequisite knowledge and skills fundamental for proficient work at each benchmark.
Novice:	This level denotes that the student is beginning to attain the prerequisite knowledge and skills that are fundamental for work at each benchmark.

Grade 4 Science

Advanced: (1) A fourth-grade student at the advanced level in science demonstrates superior performance. He/she:

(a) conducts simple experiments and identifies the variables;
(b) accurately identifies cause and effect relationships and clearly communicates these observations;
(c) consistently and accurately selects and uses appropriate devices for measurement of solids, liquids, and gases, identifying specific properties of each state of matter;
(d) recognizes multiple attributes of living things and tangible objects;
(e) often classifies objects based on subtle similarities and differences;
(f) describes and models structures, functions, and processes of living systems;
(g) thoroughly describes and creatively models the details of Earth's features and cycles;.
(h) describes and models characteristics of and changes within physical and mechanical systems;
(i) independently reads of scientific exploration in the news and discusses the possible impacts of past, present and future scientific exploration on humans and other life; and
(j) thoughtfully discusses the historical significance of scientists and the impacts of their discoveries on humans today.

Proficient: (1) A fourth-grade student at the proficient level in science demonstrates solid academic performance. He/she:

(a) with some direction, completes a simple experiment and identifies the manipulated variable;
(b) identifies cause and effect relationships and communicates these observations;
(c) accurately selects and uses devices for simple measurement of solids, liquids, and gases, identifying properties of each state of matter;
(d) recognizes attributes of living things and tangible objects and accurately classifies objects based on similarities and differences;
(e) describes structures, functions, and processes of living systems;
(f) identifies and accurately illustrates Earth's features, locating several observable changes of those features;
(g) describes characteristics of and changes within basic physical and mechanical systems;
(h) is aware of scientific exploration in the news; and
(i) discusses the possible impacts of past, present and future scientific exploration on humans, identifying the visible impacts of their discoveries on humans today.

Nearing Proficiency: (1) A fourth-grade student at the nearing proficiency level in science demonstrates partial mastery of the prerequisite knowledge and skills fundamental for proficiency in science. He/she:

(a) with specific direction, completes a simple experiment and sometimes identifies the manipulated variable;
(b) describes an observable change, but has difficulty identifying cause and effect relationships;
(c) sometimes selects the appropriate tool; and
(d) with guidance, effectively uses devices for simple measurement of solids, liquids, and gases, naming properties of each state of matter;
(e) recognizes basic attributes of living things and tangible objects and classifies objects based on two or more common attributes;
(f) sometimes describes structures, functions, and processes of living systems;
(g) names and describes Earth's features and recognizes some observable changes of those features;
(h) names components of basic physical and mechanical systems;
(i) is somewhat aware of scientific exploration in the news; and
(j) often has difficulty relating historical significance of scientists and the impacts of their discoveries on humans today.

Novice: (1) A fourth-grade student at the novice level in science is beginning to attain the prerequisite knowledge and skills that are fundamental in science. He/she:

(a) has difficulty completing a simple experiment and has limited understanding of the concept of variables;
(b) seldom describes an observable change, and rarely identifies cause and effect relationships;
(c) seldom selects the appropriate tool;
(d) even with assistance, has difficulty using devices for simple measurement of solids, liquids, and gases;
(e) has difficulty understanding the states of matter concept;
(f) sometimes recognizes concrete attributes of living things and tangible objects and groups objects based on two or more common attributes;
(g) gives limited descriptions of the structures, functions, and processes of living systems;
(h) names and, with assistance, describes Earth's features and recognizes some observable changes of those features;
(i) sometimes names components of basic physical and mechanical systems;
(j) is seldom aware of scientific exploration in the news; and
(k) seldom relates historical significance of scientists and the impacts of their discoveries on humans today.

Grade 8 Science

Advanced: (1) An eighth-grade student at the advanced level in science demonstrates superior performance. He/she:

(a) independently formulates and communicates testable questions;
(b) constructs a plan for a controlled experiment;
(c) makes accurate inferences based on observations and data;
(d) creatively illustrates how scientific knowledge changes as new evidence and understandings are learned;
(e) uses supporting details to thoughtfully explain the physical world;
(f) predicts reasonable outcomes of simple chemical reactions;
(g) makes logical connections to events in everyday life;
(h) independently and confidently identifies and classifies organisms describing a basic knowledge of common classification schemes;
(i) is aware of the interdependence of life and the environment and describes how changes affect this interrelationship;
(j) observes, uses, and interprets physical, theoretical and mathematical models to effectively demonstrate and communicate knowledge and understanding;
(k) describes and identifies some examples of how science and technology are the results of human activity throughout history; and
(l) independently seeks new information, connects past to present, is always curious about scientific discovery and its significance.

Proficient: (1) An eighth-grade student at the proficient level in science demonstrates solid academic performance. He/she:

(a) often formulates and communicates testable questions;
(b) constructs a plan for a controlled experiment;
(c) makes logical inferences based on observations;
(d) accurately interprets data, providing reasonable examples of how scientific knowledge changes as new evidence and understandings are learned;

(e) with supporting detail, describes the physical world showing an emerging understanding of simple chemical reactions, chemical formulas, and physical laws;
(f) identifies and classifies organisms and has a beginning understanding of common classification schemes;
(g) is aware of the interdependence of life and the environment;
(h) explains how characteristics of living things change because of the environment;
(i) has an emerging understanding of physical, theoretical and mathematical models;
(j) describes and identifies local examples of how science and technology are the results of human activity throughout history; and
(k) is often curious about new information and connects past to present.

Nearing Proficiency: (1) An eighth-grade student at the nearing proficiency level in science demonstrates partial mastery of the prerequisite knowledge and skills fundamental for proficiency in science. He/she:
(a) sometimes formulates and communicates testable questions;
(b) with assistance, completes a plan for a controlled experiment;
(c) has difficulty making reasonable inferences;
(d) seldom uses or interprets observations or data accurately;
(e) provides concrete examples of how scientific knowledge has changed;
(f) gives concrete explanations to describe the physical world;
(g) shows a limited understanding of simple chemical reactions, chemical formulas and physical laws;
(h) often identifies organisms, but is less sure when describing common classification schemes;
(i) provides a limited explanation of the interdependence of life and the environment;
(j) has an emerging understanding of physical models;
(k) with assistance, describes how science and technology are the results of human activity throughout history; and
(l) is sometimes curious about new information, but seldom seeks it.

Novice: (1) An eighth-grade student at the novice level in science is beginning to attain the prerequisite knowledge and skills that are fundamental in science. He/she:
(a) seldom formulates or communicates testable questions;
(b) requires direct instruction to complete a plan for a controlled experiment;
(c) has difficulty understanding inferences, observations and data;
(d) seldom provides examples of how scientific knowledge has changed;
(e) gives concrete explanations of the physical world;
(f) seldom describes even the simplest chemical reactions;
(g) identifies organisms, but has difficulty defining common classification schemes;
(h) is unable to explain the interdependence of life and the environment;
(i) sometimes uses models to describe a science concept;
(j) often doesn't make the connection that science and technology are the results of human activity throughout history; and
(k) seldom expresses interest in, or seeks out, new information.

Upon Graduation Science

Advanced: (1) A graduating student at the advanced level in science demonstrates superior performance. He/she:
(a) independently plans, conducts, and interprets experimental investigations and communicates results, articulating and supporting inferences that relate to real world applications in physical, life, and Earth sciences;
(b) consistently recognizes the interconnections within and outside science;
(c) makes thoughtful inferences about explorations and experiments;
(d) when doing physical, theoretical, and mathematical modeling, uses appropriate technology to investigate individually generated problems and/or questions about scientific phenomena;
(e) adeptly uses these skills to organize, classify, and to clearly describe interactions of the biotic and abiotic parts of the biosphere as well as the natural history of interactions of life on Earth;
(f) clearly describes and analyzes connections and interactions between and among technology, science, and society;
(g) applies scientific inquiry and technology skills to comprehend results obtained;
(h) questions validity of scientific endeavors, past and present; and
(i) makes informed decisions about scientific and social issues based on observations, data, and knowledge of the natural world.

Proficient: (1) A graduating student at the proficient level in science demonstrates solid academic performance. He/she:

(a) often plans and conducts experimental investigations;
(b) communicates results that infer real world applications in physical, life, and Earth sciences;
(c) recognizes interconnections within and outside science;
(d) makes inferences about explorations and experiments;
(e) often identifies and constructs models depicting the properties of matter in the physical world;
(f) uses appropriate technology tools and skills to investigate individually generated problems and/or questions about scientific phenomena;
(g) organizes and classifies living and nonliving things using common classification schemes;
(h) represents, models and/or discusses the interactions of the biotic and abiotic components of the Earth;
(i) describes connections and interactions between and among technology, science, and society, applying scientific inquiry and technology skills to comprehend results obtained;
(j) clearly articulates the importance of science and the historical significance to question the validity of scientific endeavor, past and present; and
(k) often makes informed decisions about scientific and social issues based on observations, data, and knowledge of the natural world.

Nearing Proficiency: (1) A graduating student at the nearing proficiency level in science demonstrates partial mastery of the prerequisite knowledge and skills fundamental for proficiency in science. He/she:

(a) conducts and communicates results from simple experimental investigations, sometimes inferring real world applications;
(b) recognizes interconnections within and outside science;
(c) sometimes makes inferences about explorations and experiments;
(d) identifies and, with guidance, constructs models depicting the properties of matter in the physical world;
(e) uses limited skills with technology to investigate teacher-guided problems and/or questions about scientific phenomena;
(f) organizes and sometimes classifies living and nonliving things using common classification schemes;
(g) with assistance, identifies, models, and discusses the interactions of the biotic and abiotic components of the Earth;
(h) sometimes communicates interactions of science, technology, and society;
(i) sometimes defines the importance of science and its historical importance;
(j) is generally accepting of the validity of scientific endeavor; and
(k) sometimes formulates a decision about scientific and social issues based on observations, data, and knowledge of the natural world.

Novice: (1) A graduating student at the novice level in science is beginning to attain the prerequisite knowledge and skills that are fundamental in science. He/she:

(a) has difficulty conducting and communicating the results from a simple experimental investigation, seldom inferring real world applications;
(b) sometimes recognizes interconnections within and outside science;
(c) struggles to make inferences about explorations and experiments and makes simple predictions based upon knowledge of matter in the physical world;
(d) with guidance, selects and uses appropriate technology to investigate teacher-generated problems or questions;
(e) rarely recognizes common classification schemes or relates interactions of the biotic and abiotic factors in the environment;
(f) identifies, but inconsistently communicates interactions of science, technology, and society;
(g) has difficulty defining the importance of science and it's historical significance;
(h) seldom questions the validity of scientific endeavor, past and present; and
(i) seldom makes informed decisions, about issues, based on observations and knowledge of the natural world.

Science Examples

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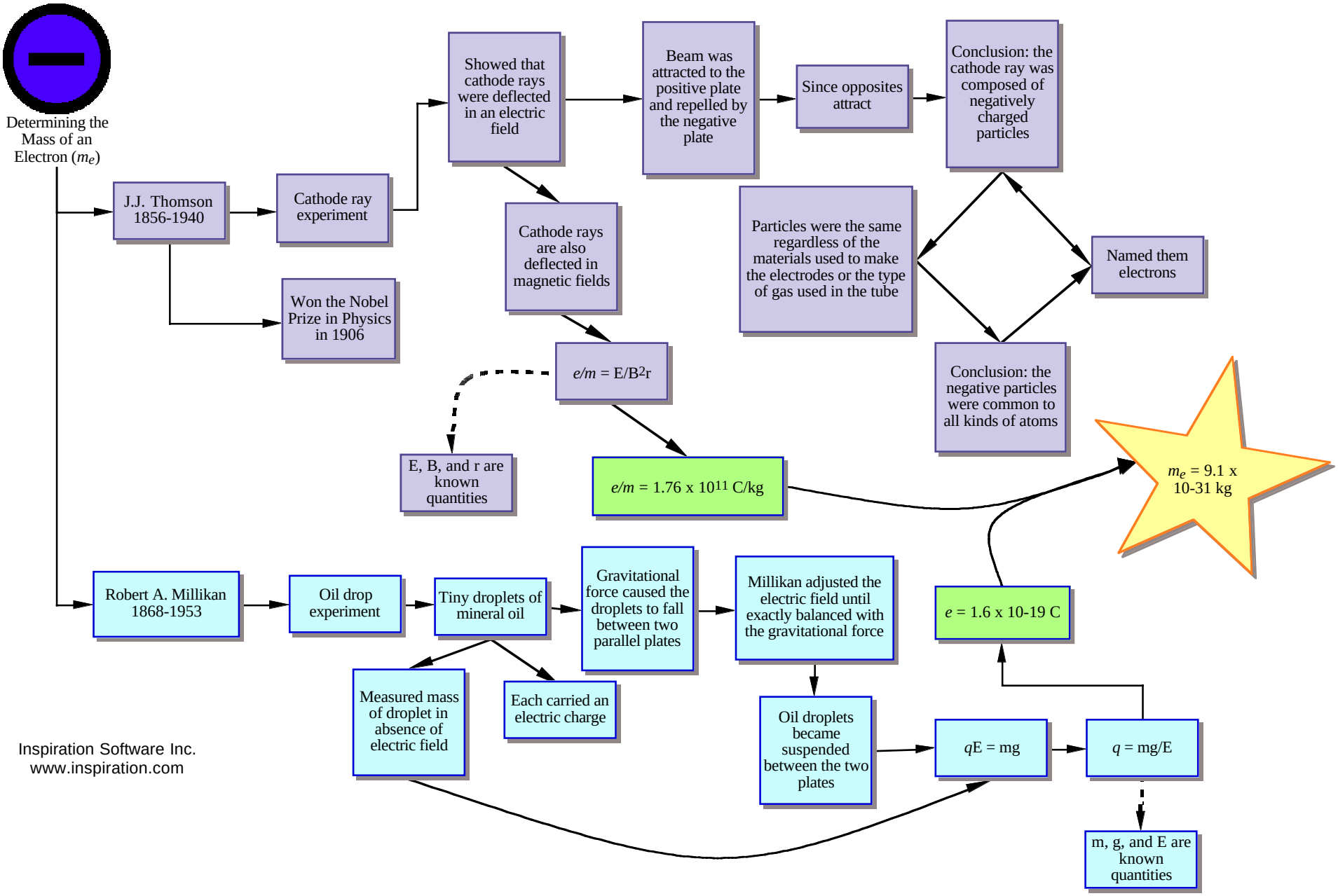
Determining the Mass of an Electron (m_e)
J.J. Thomson 1856-1940
Cathode ray experiment
Showed that cathode rays were deflected in an electric field
Beam was attracted to the positive plate and repelled by the negative plate
Since opposites attract
Conclusion: the cathode ray was composed of negatively charged particles
Won the Nobel Prize in Physics in 1906
Cathode rays are also deflected in magnetic fields
Particles were the same regardless of the materials used to make the electrodes or the type of gas used in the tube
Named them electrons
Conclusion: the negative particles were common to all kinds of atoms
$e/m = E/B^2r$
E, B, and r are known quantities
e/m = 1.76 x 10^{11} C/kg
m_e = 9.1 x 10-31 kg
Robert A. Millikan 1868-1953
Oil drop experiment
Tiny droplets of mineral oil
Gravitational force caused the droplets to fall between two parallel plates
Millikan adjusted the electric field until exactly balanced with the gravitational force
e = 1.6 x 10-19 C
Measured mass of droplet in absence of electric field
Each carried an electric charge
Oil droplets became suspended between the two plates
$qE = mg$
$q = mg/E$
m, g, and E are known quantities
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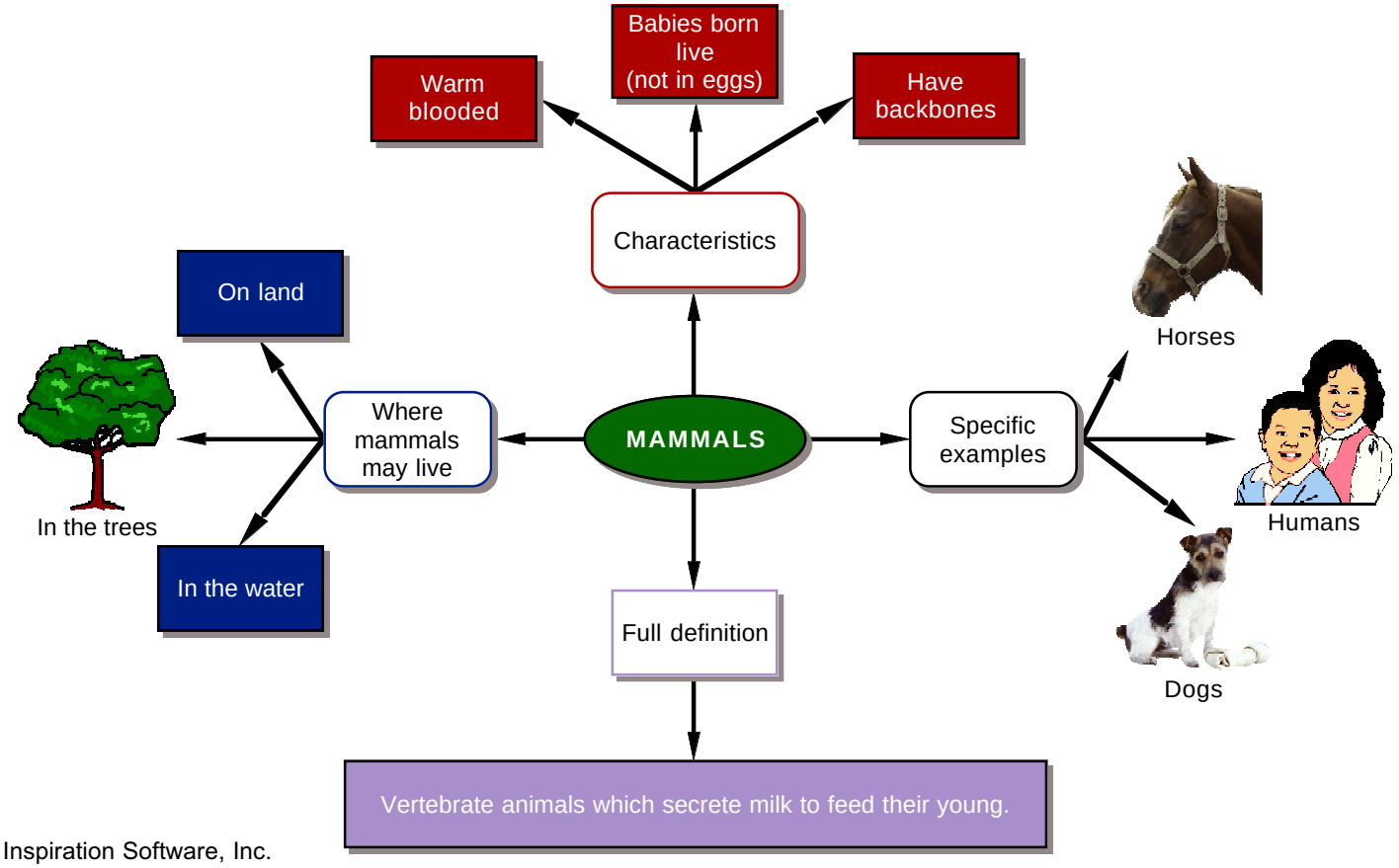

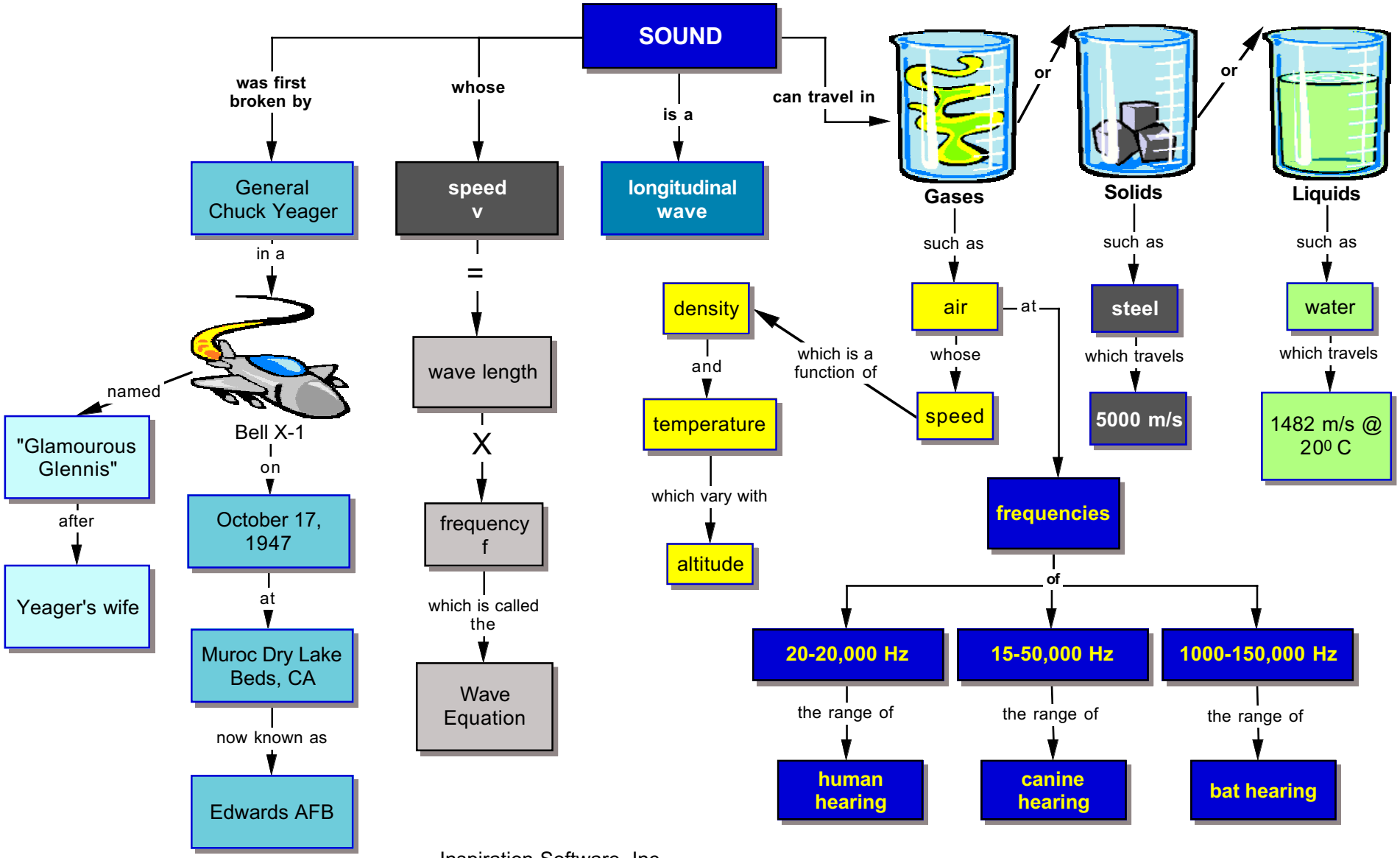

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