§112.XX. Earth and Space Science

(a) **General requirements.** Students shall be awarded one credit for successful completion of this course. Required prerequisites: three units of science, one of which may be taken concurrently, and three units of mathematics, one of which may be taken concurrently. This course is recommended for students in grade 12 but may be taken by students in grade 11.

(b) **Introduction.**

(1) Earth and Space Science (ESS) is a capstone course designed to build on students' prior scientific and academic knowledge and skills to develop understanding of the Earth System in space and time.

(2) **NATURE OF SCIENCE**
Science, as defined by the National Academy of Sciences, is the "use of evidence to construct testable explanations and predictions of natural phenomena, as well as the knowledge generated through this process." This vast body of changing and increasing knowledge is described by physical, mathematical, and conceptual models. Students should know that some questions are outside the realm of science because they deal with phenomena that are not scientifically testable.

(3) **SCIENTIFIC INQUIRY**
Scientific inquiry is the planned and deliberate investigation of the natural world. Scientific methods of investigation can be experimental, descriptive, or comparative. The method chosen should be appropriate to the question being asked.

(4) **SCIENCE AND SOCIAL ETHICS**
Scientific decision-making is a way of answering questions about the natural world. Students should be able to distinguish between scientific decision-making methods and ethical/social decisions that involve the application of scientific information.

(5) **EARTH AND SPACE SCIENCE THEMES**
An Earth systems approach to the themes of Earth in Space and Time, Solid Earth, and Fluid Earth defined the selection and development of the concepts discussed below.

(A) **Earth in Space and Time.** Earth has a long, complex, and dynamic history. Advances in technologies continue to further our understanding of the origin, evolution, and properties of the Earth and planetary systems within a chronological framework. The origin and distribution of resources that sustain life on Earth are the result of interactions among Earth's subsystems over billions of years.

(B) **Solid Earth.** The geosphere is a collection of complex, interacting, dynamic subsystems linking Earth's interior to its surface. The geosphere is composed of materials that move between subsystems at various rates driven by the uneven distribution of thermal energy. These dynamic processes are responsible for the origin and distribution of resources as well as geologic hazards that impact society.

(C) **Fluid Earth.** The fluid Earth consists of the hydrosphere, cryosphere, and atmosphere subsystems. These subsystems interact with the biosphere and geosphere resulting in complex biogeochemical and geochemical cycles. The global ocean is the thermal energy reservoir for surface processes and, through interactions with the atmosphere, influences climate. Understanding these interactions and cycles over time has implications for life on Earth.

(6) EARTH AND SPACE SCIENCE STRANDS

The course has three strands used throughout each of the three themes: systems, energy, and relevance.

(A) **Systems.** A system is a collection of interacting physical, chemical and biological processes that involves the flow of matter and energy on different temporal and spatial scales. The Earth system is composed of interdependent and interacting subsystems of the geosphere, hydrosphere, atmosphere, cryosphere, and biosphere within a larger planetary and stellar system. Change and constancy occur in Earth's system and can be observed, measured as patterns and cycles, and described or presented in models used to predict how the Earth system changes over time.

(B) **Energy.** The uneven distribution of Earth's internal and external thermal energy is the driving force for complex, dynamic and continuous interactions and cycles in Earth subsystems. These interactions are responsible for the movement of matter within and between the subsystems resulting in, for example, plate motions and ocean-atmosphere circulation.

(C) **Relevance**. The interacting components of the Earth system change by both natural and human-influenced processes. Natural processes include hazards such as flooding, earthquakes, volcanoes, hurricanes, meteorite impacts, and climate change. Some human-influenced processes, such as pollution and nonsustainable use of Earth's natural resources, may damage the Earth system. Examples include climate change, soil erosion, air and water pollution, and biodiversity loss. The time scale of these changes and their impact on human society must be understood to make wise decisions concerning the use of the land, water, air, and natural resources. Proper stewardship of Earth will prevent unnecessary degradation and destruction of Earth's subsystems and diminish detrimental impacts to individuals and society.

(c) Knowledge and skills.

(1) Scientific processes. The student conducts laboratory and field investigations for at least 40% of instructional time using safe, environmentally appropriate, and ethical practices. The student is expected to:

(A) demonstrate safe practices during laboratory and field investigations;

(B) make wise choices in the use and conservation of resources and the disposal or recycling of materials; and

(C) use the school's technology and information systems in a wise and ethical manner.

(2) Scientific processes. The student uses scientific methods during laboratory and field investigations. The student is expected to:

(A) know that scientific hypotheses are tentative and testable statements that must be capable of being supported or not supported by observational evidence. Hypotheses of durable explanatory power which have been tested over a wide variety of conditions are incorporated into theories.

(B) know that scientific theories are based on natural and physical phenomena and are capable of being tested by multiple independent researchers. Unlike hypotheses, scientific theories are well-established and highly reliable explanations, but may be subject to change as new areas of science and new technologies are developed.

(C) distinguish between scientific hypotheses and scientific theories.

(D) demonstrate the use of course equipment, techniques, and procedures, including computers and web-based computer applications;

(E) use a wide variety of additional course apparatuses, equipment, techniques, and procedures as appropriate, such as satellite imagery and other remote sensing data, Geographic Information Systems (GIS), Global Positioning System (GPS), scientific probes, microscopes, telescopes, modern video and image libraries, weather station, fossil and rock kits, bar magnets, coiled springs, wave simulators, tectonic plate models, and planetary globes;

(F) organize, analyze, evaluate, make inferences, and predict trends from data;

(G) use mathematical procedures such as algebra, statistics, scientific notation, and significant figures to analyze data using SI units; and

(H) communicate valid conclusions supported by the data using several formats, such as technical reports, lab reports, labeled drawings, graphic organizers, journals, presentations, and technical posters.

(3) **Scientific processes.** The student uses critical thinking, scientific reasoning, and problem solving to make informed decisions within and outside the classroom. The student is expected to:

(A) analyze and evaluate scientific explanations using empirical evidence, logical reasoning, and experimental and observational testing;

(B) analyze, evaluate, communicate and apply scientific information extracted from written text such as current events, news reports, published journal articles, and marketing materials;

(C) evaluate the impact of research on scientific thought, society, and public policy;

(D) explore careers and collaboration among scientists in Earth and space sciences;

(E) learn and understand the contributions of scientists to the historical development of the Earth and space sciences; and

(4) **Earth in space and time.** The student knows how Earth-based and space-based astronomical observations reveal the structure, scale, composition, origin, and history of the universe. The student is expected to:

(A) evaluate the evidence concerning the Big Bang model, such as red shift and cosmic microwave background radiation, and the concept of an expanding universe that originated about 14 billion years ago;

(B) explain how the Sun and other stars transform matter into energy through nuclear fusion; and

(C) investigate the process by which a supernova can lead to the formation of successive generation stars and planets.

(5) **Earth in space and time.** The student knows that Earth's place in the solar system is explained by the solar nebular accretionary disk model. The student is expected to:

(A) analyze how gravitational condensation of solar nebular gas and dust can lead to the accretion of planetesimals and protoplanets;

(B) investigate sources of heat, including kinetic heat of impact accretion, gravitational compression, and radioactive decay, which allows protoplanet differentiation into layers;

(C) contrast the characteristics of comets, asteroids, meteoroids, and their positions in the solar system including the orbital regions of the terrestrial planets, the asteroid belt, gas giants, Kuiper Belt, and Oort Cloud;

(D) explore the historical and current hypotheses for the origin of the Moon, including the collision of Earth with a Mars-sized planetesimal;

(E) compare terrestrial planets to gas giant planets in the solar system, including structure, composition, size, density, orbit, surface features, tectonic activity, temperature, and suitability for life; and

(F) compare extra-solar planets with planets in our solar system, and describe how such planets are detected.

(6) **Earth in space and time.** The student knows the evidence for how Earth's atmospheres, hydrosphere, and geosphere formed and changed through time. The student is expected to:

(A) analyze the changes of Earth's atmosphere through time from the original hydrogen-helium atmosphere, the carbon dioxide-water vapor-methane atmosphere, and the current nitrogen-oxygen atmosphere;

(B) evaluate the role of volcanic outgassing and impact of water-bearing comets in developing Earth's atmosphere and hydrosphere;

(C) investigate how the formation of atmospheric oxygen and the ozone layer impacted the formation of the geosphere and biosphere; and

(D) evaluate how Earth's cooling led to tectonic activity, resulting in continents and ocean basins.

(7) **Earth in space and time.** The student knows that scientific dating methods of fossils and rock sequences are used to construct a chronology of Earth's history expressed in the geologic time scale. The student is expected to:

(A) evaluate relative dating methods using original horizontality, rock superposition, lateral continuity, cross-cutting relationships, unconformities, index fossils, and biozones based on fossil succession to determine chronological order;

(B) apply radiometric dating methods that can be used to calculate the ages of igneous rocks from Earth and Moon, and meteorites; and

(C) understand how multiple dating methods are used to construct the geologic time scale, which represents Earth's approximate 4.6 billion year history;

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(8) **Earth in space and time.** The student knows that fossils provide evidence for geological and biological evolution. Students are expected to:

(A) evaluate a variety of fossil types, transitional fossils, fossil lineages, and significant fossil deposits with regard to their appearance, completeness, and rate and diversity of evolution;

(B) explain how sedimentation, fossilization, and speciation affect the degree of completeness of the fossil record; and

(C) evaluate the significance of the terminal Permian and Cretaceous mass extinction events, including adaptive radiations of organisms after the events.

(9) **Solid Earth.** The student knows Earth's interior is differentiated chemically, physically and thermally. The student is expected to:

(A) evaluate heat transfer through Earth's subsystems by radiation, convection, and conduction; include its role in plate tectonics, volcanism, ocean circulation, weather, and climate;

(B) examine the chemical, physical, and thermal structure of Earth's crust, mantle, and core including the lithosphere and asthenosphere;

(C) explain how scientists use geophysical methods, such as seismic wave analysis, gravity, and magnetism to interpret Earth's structure; and

(D) describe the formation and structure of the Earth's magnetic field including its interaction with charged solar particles to form the Van Allen belts and auroras.

(10) **Solid Earth.** The student knows that plate tectonics is the global mechanism for major geologic processes and that heat transfer, governed by the principles of thermodynamics, is the driving force. The student is expected to:

(A) investigate how new conceptual interpretations of data and innovative geophysical technologies led to the current theory of plate tectonics;

(B) describe how heat and rock composition affect density within Earth's interior and how density influences the development and motion of Earth's tectonic plates;

(C) explain how plate tectonics accounts for geologic processes and features, including sea floor spreading, ocean ridges and rift valleys, subduction zones, earthquakes, volcanoes, mountain ranges, hot spots, and hydrothermal vents;

(D) calculate the motion history of tectonic plates using equations relating rate, time, and distance to predict future motions, locations, and resulting geologic features;

(E) distinguish the location, type, and relative motion of convergent, divergent, and transform plate boundaries using evidence from the distribution of earthquakes and volcanoes; and

(F) evaluate the role of plate tectonics with respect to long-term global changes in Earth's subsystems, such as continental buildup, glaciation, sea level fluctuations, mass extinctions, and climate change.

(11) **Solid Earth.** The student knows that the geosphere continuously changes over a range of time scales involving dynamic and complex interactions among Earth's subsystems. The student is expected to:

(A) compare the roles of erosion, deposition, and igneous activity by lava, water, wind, ice, and gravity in constantly reshaping Earth's surface;

(B) explain how plate tectonics accounts for geologic surface processes and features including folds, faults, sedimentary basin formation, mountain building, and continental accretion;

(C) analyze changes in continental plate configurations, such as Pangaea, and their impact on the biosphere, atmosphere and hydrosphere through time;

(D) interpret Earth surface features using a variety of methods such as satellite imagery, aerial photography, topographic and geologic maps using appropriate technologies; and

(E) evaluate the impact of changes in Earth's subsystems on humans, such as earthquakes, tsunamis, volcanic eruptions, hurricanes, flooding, and storm surges; and the impact of humans on Earth's subsystems, such as population growth, fossil fuel burning, and use of fresh water.

(12) **Solid Earth.** The student knows that Earth contains energy, water, mineral, and rock resources, and that use of these resources impacts Earth's subsystems. The student is expected to:

(A) evaluate how the use of energy, water, mineral, and rock resources affects Earth's subsystems;

(B) describe the formation of fossil fuels, including petroleum and coal;

(C) discriminate between renewable and nonrenewable resources based upon rate of formation and use;

(D) analyze the economics of resources from discovery to disposal, including technological advances, resource type, concentration and location, waste disposal and recycling, and environmental costs; and

(E) explore careers that involve the exploration, extraction, production, use, and disposal of Earth's resources.

(13) **Fluid Earth.** The student knows that the fluid Earth is composed of the hydrosphere, cryosphere, and atmosphere subsystems that interact on various time scales with the biosphere and geosphere. The student is expected to:

(A) quantify the components and fluxes within the hydrosphere, such as changes in polar ice caps and glaciers, salt water incursions, and groundwater levels in response to precipitation events or excessive pumping;

(B) analyze how global ocean circulation is the result of wind, tides, the Coriolis effect, water density differences, and the shape of the ocean basins;

(C) analyze the empirical relationship between the emissions of carbon dioxide, atmospheric carbon dioxide levels, and the average global temperature trends over the past 150 years;

(D) discuss mechanisms and causes, such as selective absorbers, major volcanic eruptions, solar luminance, giant meteorite impacts, and human activities that result in significant changes in Earth's climate;

(E) investigate the causes and history of eustatic sea-level changes that result in transgressive and regressive sedimentary sequences; and

(F) discuss scientific hypotheses for the origin of life by abiotic chemical processes in an aqueous environment through complex geochemical cycles.

(14) **Fluid Earth.** The student knows that Earth's global ocean stores solar energy, and is a major driving force for weather and climate through complex atmospheric interactions. The student is expected to:

(A) analyze the uneven distribution of solar energy on Earth's surface, including differences in atmospheric transparency, surface albedo, Earth's tilt, duration of insolation, and differences in atmospheric and surface absorption of energy;

(B) investigate how the atmosphere is heated from Earth's surface due to absorption of solar energy, which is re-radiated as thermal energy and trapped by selective absorbers; and

(C) explain how thermal energy transfer between the ocean and atmosphere drives surface currents, thermohaline currents, and evaporation that influences climate.

(15) **Fluid Earth.** The student knows that interactions among Earth's five subsystems influence climate and resource availability, which affect Earth's habitability. The student is expected to:

(A) describe how changing surface-ocean conditions, including El Nino-Southern Oscillation, affect global weather and climate patterns;

(B) investigate evidence, such as ice cores, glacial striations, and fossils, for climate variability and its use in developing computer models to explain present and predict future climates;

(C) quantify the dynamics of surface and groundwater movement, such as recharge, discharge, evapotranspiration, storage, residence time, and sustainability;

(D) explain the global carbon cycle, including how carbon exists in different forms within the five subsystems and how these forms affect life; and

(E) analyze recent global ocean temperature data to predict the consequences of changing ocean temperature on evaporation, sea level, algal growth, coral bleaching, hurricane intensity, and biodiversity.

End of Earth and Space Science