Earth and Space Science, Grade 12

University Preparation SES4U

This course develops students' understanding of Earth and its place in the universe. Students will investigate the properties of and forces in the universe and solar system and analyse techniques scientists use to generate knowledge about them. Students will closely examine the materials of Earth, its internal and surficial processes, and its geological history, and will learn how Earth's systems interact and how they have changed over time. Throughout the course, students will learn how these forces, processes, and materials affect their daily lives. The course draws on biology, chemistry, physics, and mathematics in its consideration of geological and astronomical processes that can be observed directly or inferred from other evidence.

Prerequisite: Science, Grade 10, Academic

Big Ideas

Astronomy (Science of the Universe)

- The development of more sophisticated technologies has enabled us to achieve a deeper, more thorough understanding of the origin and evolution of the universe.
- Scientific theories about the universe are refined and altered as new evidence is discovered.

Planetary Science (Science of the Solar System)

- Space exploration and the technologies that have been developed to facilitate it have had positive and negative effects on society, the economy, and the environment.
- Space exploration presents many hazards.
- Interactions among bodies within the solar system have an impact on the existence of life.

Recording Earth's Geological History

- Earth is very old, and its atmosphere, hydrosphere, and lithosphere have undergone many changes over time.
- Changing conditions on Earth over time have had positive and negative effects on life on the planet.

Earth Materials

- Exploration for and extraction and refining of materials from below the surface of Earth have positive and negative effects on the economy, society, and the environment.
- Different types of rocks have different origins, properties, characteristics, and uses.

Geological Processes

- Earth's lithosphere is constantly changing as the result of natural phenomena and human activity.
- Specialized technologies have enabled us to increase our knowledge and understanding of Earth's structure and have improved the ability of scientists to monitor and predict changes in the lithosphere.

Fundamental Concepts Covered in This Course (see also page 5)

Fundamental Concepts	Astronomy (Science of the Universe)	Planetary Science (Science of the Solar System)	Recording Earth's Geological History	Earth Materials	Geological Processes
Matter	✓	✓	✓	✓	✓
Energy	✓	✓	✓	✓	
Systems and Interactions		✓	✓		✓
Structure and Function				✓	
Sustainability and Stewardship		✓	✓	✓	✓
Change and Continuity	✓	✓	✓		✓

A. SCIENTIFIC INVESTIGATION SKILLS AND CAREER EXPLORATION

OVERALL EXPECTATIONS

Throughout this course, students will:

A1. demonstrate scientific investigation skills (related to both inquiry and research) in the four areas of skills (initiating and planning, performing and recording, analysing and interpreting, and communicating);

A2. identify and describe careers and Canadian contributions related to the fields of science under study.

SPECIFIC EXPECTATIONS

A1. Scientific Investigation Skills

Throughout this course, students will:

Initiating and Planning [IP]*

A1.1 formulate relevant scientific questions about observed relationships, ideas, problems, or issues, make informed predictions, and/or formulate educated hypotheses to focus inquiries or research

A1.2 select appropriate instruments (e.g., hand lens, spectrographs, rock hammers) and materials (e.g., star charts, geological maps, mineral identification kits), and identify appropriate methods, techniques, and procedures, for each inquiry

A1.3 identify and locate a variety of print and electronic sources that enable them to address research topics fully and appropriately

A1.4 apply knowledge and understanding of safe laboratory and field work practices and procedures when planning investigations by correctly interpreting Workplace Hazardous Materials Information System (WHMIS) symbols; by using appropriate techniques for handling and storing laboratory equipment and materials and disposing of laboratory materials (e.g., following safety procedures when collecting samples; using materials safely when identifying minerals and rocks); and by using appropriate personal protection (e.g., wearing safety goggles when testing rock or mineral samples; using proper protective eyewear when observing the sun)

Performing and Recording [PR]*

A1.5 conduct inquiries, controlling relevant variables, and adapting or extending procedures as required, and using appropriate materials and equipment safely, accurately, and effectively, to collect observations and data

A1.6 compile accurate observations and data from laboratory and other sources (e.g., field work), and organize and record the data, using appropriate formats, including tables, flow charts, graphs, and/or diagrams

A1.7 select, organize, and record relevant information on research topics from a variety of appropriate sources, including electronic, print, and/or human sources (e.g., personal communication), using suitable formats and an accepted form of academic documentation

Analysing and Interpreting [AI]*

A1.8 synthesize, analyse, interpret, and evaluate qualitative and/or quantitative data to determine whether the evidence supports or refutes the initial prediction or hypothesis and whether it is consistent with scientific theory; identify sources of bias and/or error; and suggest improvements to the inquiry to reduce the likelihood of error

A1.9 analyse the information gathered from research sources for logic, accuracy, reliability, adequacy, and bias

A1.10 draw conclusions based on inquiry results and research findings, and justify their conclusions with reference to scientific knowledge

* The abbreviation(s) for the broad area(s) of investigation skills – IP, PR, AI, and/or C – are provided in square brackets at the end of the expectations in strands B–F to which the particular area(s) relate (see pp. 20–22 for information on scientific investigation skills).

Communicating [C]*

A1.11 communicate ideas, plans, procedures, results, and conclusions orally, in writing, and/or in electronic presentations, using appropriate language and a variety of formats (e.g., data tables, laboratory reports, presentations, debates, simulations, models)

A1.12 use appropriate numeric (e.g., SI and imperial units), symbolic, and graphic modes of representation (e.g., use appropriate time scales when representing geological time, or appropriate units to represent astronomical distances)

A1.13 express the results of any calculations involving data accurately and precisely, to the appropriate number of decimal places or significant figures

A2. Career Exploration

Throughout this course, students will:

A2.1 identify and describe a variety of careers related to the field of science under study (e.g., astronomer, paleontologist, astrophysicist, geologist, professor, planetarium curator) and the education and training necessary for these careers

A2.2 describe the contributions of scientists, including Canadian scientists (e.g., Alice Wilson, George M. Dawson, Thomas Edvard Krogh, William E. Logan, Richard Bond, Helen Sawyer Hogg, Joseph B. Tyrrell), to the fields under study

B. ASTRONOMY (SCIENCE OF THE UNIVERSE)

OVERALL EXPECTATIONS

By the end of this course, students will:

B1. analyse the development of technologies that have contributed to our understanding of the universe, and evaluate the impact of milestones in astronomical theory or knowledge on the scientific community;

B2. investigate and analyse the properties of the universe, particularly the evolution and properties of stars, in both qualitative and quantitative terms;

B3. demonstrate an understanding of the origin and evolution of the universe, the principal characteristics of its components, and techniques used to study those components.

SPECIFIC EXPECTATIONS

B1. Relating Science to Technology, Society, and the Environment

By the end of this course, students will:

B1.1 analyse a major milestone in astronomical knowledge or theory (e.g., the discovery of the red shift in the spectra of galaxies; the knowledge gathered from the particle accelerator experiments at CERN in Switzerland), and explain how it revolutionized thinking in the scientific community [AI, C]

Sample issue: Prior to Copernicus, astronomers generally believed that Earth was the centre of the universe. Copernicus's heliocentric thesis had a revolutionary impact not only on astronomy but on other areas of science as well.

Sample questions: How did the approach used by Galileo to support heliocentric thesis differ from Greek speculative philosophy about the structure of the universe? What impact did Galileo's findings have on other astronomers and on scientists in general? How did Kepler's calculations and mathematical models differ from earlier explanations of celestial motion? How did they influence subsequent astronomers? How has Brahe's work affected our view of our planet?

B1.2 analyse why and how a particular technology related to astronomical research was developed and how it has been improved over time (e.g., the evolution from optical to radio telescopes and to the Hubble telescope) [AI, C]

Sample issue: In 1933, K.G. Jansky built a radio telescope to identify sources of static interference affecting telephone transmission. He discovered that much of the static came from deep within the Milky Way. Radio telescopes have since been modified to include large parabolic dishes, which are used to study pulsars, quasars, and black holes.

Sample questions: What technologies in astronomical research were originally developed for military uses? In what ways have they been refined for scientific use? How has light collection and focusing improved with the use of the liquid mercury telescope operated by the University of British Columbia and Laval University? Why was the Sudbury Neutrino Observatory built? How have developments over time improved its usefulness?

B2. Developing Skills of Investigation and Communication

By the end of this course, students will:

B2.1 use appropriate terminology related to astronomy, including, but not limited to: *Doppler effect, electromagnetic radiation, protostar, celestial equator, ecliptic, altitude and azimuth,* and *right ascension and declination* [C]

B2.2 locate observable features of the night sky using star charts, computer models, or direct observation, and record the location of these features using astronomical terms (e.g., celestial equator, ecliptic) and systems (e.g., altitude and azimuth, right ascension and declination) [PR, C]

B2.3 analyse spectroscopic data mathematically or graphically to determine various properties of stars (e.g., determine surface temperature from peak wavelength using Wein's law; predict chemical composition from spectral absorption lines; determine motion using the Doppler effect) [AI, C]

B2.4 use the Hertzsprung-Russell diagram to determine the interrelationships between the properties of stars (e.g., between mass and luminosity, between colour and luminosity) and to investigate their evolutionary pathways [PR, AI]

B2.5 investigate, in quantitative terms, properties of stars, including their distance from Earth (using the parallax method), surface temperature, absolute magnitude, and luminosity [PR, AI]

B2.6 investigate, using photographs or diagrams, the basic features of different types of galaxies (e.g., elliptical, spiral, barred spiral, irregular, peculiar), including the Milky Way [PR]

B3. Understanding Basic Concepts

By the end of this course, students will:

B3.1 describe the theoretical and evidential underpinnings of the big bang theory (e.g., the theory that cosmic microwave background radiation is an echo of the big bang; physical evidence of the mass of the universe, and the relationship between mass and gravity) and their implications for the evolution of the universe

B3.2 explain the scale of distances between celestial bodies (e.g., with reference to astronomical units, light years, and parsecs) and the methods astronomers use to determine these distances (e.g., stellar parallax, cepheid variables)

B3.3 describe the characteristics of electromagnetic radiation (e.g., the relationship between wavelength, frequency, and energy) and the ways in which each region of the electromagnetic spectrum is used in making astronomical observations (e.g., X-rays in the search for black holes; infrared radiation to see through interstellar dust)

B3.4 explain how stars are classified on the basis of their surface temperature, luminosity, and chemical composition

B3.5 explain, with reference to a specific star (e.g., Rigel, Sirius, Arcturus), how astronomers use techniques to determine the properties of stars (e.g., mass, diameter, magnitude, temperature, luminosity)

B3.6 describe the sequence of events in the life cycle of a star, from its formation to the main sequence phase and beyond, with specific reference to energy sources and forces involved

B3.7 explain the relationship between the type of death of a star and the star's initial mass (e.g., a star with a low mass will form a planetary nebula and a white dwarf)

C. PLANETARY SCIENCE (SCIENCE OF THE SOLAR SYSTEM)

OVERALL EXPECTATIONS

By the end of this course, students will:

C1. analyse political, economic, and environmental issues related to the exploration and study of the solar system, and how technology used in space exploration can be used in other areas of endeavour;

C2. investigate features of and interactions between bodies in the solar system, and the impact of these features and interactions on the existence of life;

C3. demonstrate an understanding of the internal (geological) processes and external (cosmic) influences operating on bodies in the solar system.

SPECIFIC EXPECTATIONS

C1. Relating Science to Technology, Society, and the Environment

By the end of this course, students will:

C1.1 analyse political considerations related to, and economic and environmental consequences (actual and/or potential) of, exploration of the solar system (e.g., political pressures underlying the original Space Race; the ability to monitor environmental conditions from space) [AI, C]

Sample issue: As we deplete Earth's natural resources, researchers are studying the feasibility of supplementing those resources through space mining. Asteroids and other bodies in the solar system are potentially rich sources of minerals and other valuable substances, but their exploitation raises a range of legal, economic, environmental, and technological questions.

Sample questions: What are some of the dangers to terrestrial life and to space travellers of the orbital debris from space travel and study? What types of factors affect government decisions about allocating funds for space exploration? Is the investment made in space exploration money well spent? Why or why not?

C1.2 analyse, on the basis of research, a specific technology that is used in space exploration and that has applications in other areas of research or in the environmental sector (e.g., Canadian satellites and robotics, spacecraft technologies, ground base and orbital telescopes, devices to mitigate the effects of the space environment on living organisms), and communicate their findings [IP, PR, AI, C]

Sample issue: The Canadarms were developed for space shuttle missions and the International Space Station. However, the robotic arms have other applications, including inspecting and cleaning up hazardous substances, servicing nuclear power plants, repairing pipelines on the ocean floor, mining in areas too inhospitable for humans, and conducting remote or microsurgery.

Sample questions: How are Landsat and radar from space shuttles used in archaeological research, costal studies, and the monitoring of natural disasters? How can technologies developed for space travel be used in water purification and waste treatment on Earth? How is remote sensing used to monitor atmospheric changes, such as changes in the ozone layer? How is remote sensing used to monitor changes to ecosystems?

C2. Developing Skills of Investigation and Communication

By the end of this course, students will:

C2.1 use appropriate terminology related to planetary science, including, but not limited to: *solar system*, *geocentric*, *heliocentric*, *geodesy*, *geosynchronous*, *eccentricity*, *apogee*, *aphelion*, *perigee*, and *perihelion* [C]

C2.2 identify geological features and processes that are common to Earth and other bodies in the solar system (e.g., craters, faults, volcanic eruptions), and create a model or illustration to show these features, using data and images from satellites and space probes [PR, AI, C]

C2.3 use an inquiry or research process to investigate the effects of various forms of radiation and high-energy particles on bodies, organisms, and devices within the solar system (e.g., the effects of cosmic rays on atmospheric phenomena, of ultraviolet light on human and animal eyes and skin, of solar wind on radio communications) [IP, PR]

C2.4 investigate the ways in which interactions between solid bodies have helped to shape the solar system, including Earth (e.g., the accretion of minor bodies, the formation of moons, the formation of planetary rings) [PR]

C2.5 investigate the properties of Earth that protect life from hazards such as radiation and collision with other bodies (e.g., Earth's orbital position helps protect it from asteroids, some of which are deflected by the Jovian planets; Earth's magnetic field protects the planet from solar wind; atmospheric ozone minimizes incoming ultraviolet radiation) [PR]

C2.6 investigate techniques used to study and understand objects in the solar system (e.g., the measurement of gravitational pull on space probes to determine the mass of an object, the use of spectroscopy to study atmospheric compositions, the use of the global positioning system to track plate movement and tectonic activity from space) [PR]

C3. Understanding Basic Concepts

By the end of this course, students will:

C3.1 explain the composition of the solar system (e.g., the sun, terrestrial inner planets, the asteroid belt, gas giant outer planets, the Kuiper belt, the scattered disc, the heliopause, the Oort cloud), and describe the characteristics of each component

C3.2 identify and explain the classes of objects orbiting the sun (e.g., planets, dwarf planets, small solar system bodies [SSSBs])

C3.3 explain the formation of the solar system with reference to the fundamental forces and processes involved (e.g., how gravitational force led to the contraction of the original solar nebula)

C3.4 identify the factors that determined the properties of bodies in the solar system (e.g., differences in distance from the sun result in temperature variations that determine whether substances on a planet, moon, or other body are solid or gaseous)

C3.5 identify and explain the properties of celestial bodies within or beyond the solar system, other than Earth, that might support the existence of life (e.g., the possible existence of liquid water on Europa; the proximity of a body to its host star)

C3.6 compare Earth with other objects in the solar system with respect to properties such as mass, size, composition, rotation, magnetic field, and gravitational field

C3.7 identify Kepler's laws, and use them to describe planetary motions (e.g., the shape of their orbits; differences in their orbital velocity)

C3.8 identify Newton's laws, and use them to explain planetary motion

C3.9 describe the major external processes and phenomena that affect Earth (e.g., radiation and particles from the "quiet" and "active" sun; cosmic rays; gravity of the sun and moon; asteroidal and cometary debris, including their force, energy, and matter)

D. RECORDING EARTH'S GEOLOGICAL HISTORY

OVERALL EXPECTATIONS

By the end of this course, students will:

D1. analyse, with reference to geological records, the relationship between climate, geology, and life on Earth, and evaluate contributions to our understanding of changes in Earth systems over geological time;

D2. investigate geological evidence of major changes that have occurred during Earth's history, and of the various processes that have contributed to these changes;

D3. demonstrate an understanding of how changes to Earth's surface have been recorded and preserved throughout geological time and how they contribute to our knowledge of Earth's history.

SPECIFIC EXPECTATIONS

D1. Relating Science to Technology, Society, and the Environment

By the end of this course, students will:

D1.1 analyse the relationship between climate and geology, and, using geological records, assess the impact of long-term climate change on life on Earth [AI, C]

Sample issue: Geological records provide scientists with important evidence about climate change and changes in life on Earth. Not all scientists agree about the significance and meaning of geological evidence, however, and there is disagreement about the accuracy of some dating techniques.

Sample questions: What do changes in atmospheric conditions recorded throughout the geological record tell us about past and present environmental conditions? How have the patterns of ocean currents changed as a result of continental drift, and how has this affected Earth's climate? What environmental and evolutionary changes are seen from the Devonian period to the Carboniferous period?

D1.2 evaluate the significance of contributions, including Canadian contributions, to our understanding of geological time and of changes in Earth systems over time (e.g., the contributions of Raymond A. Price; the Canadian contribution to the development of Landsat) [AI, C]

Sample issue: Canadian geologist John Tuzo Wilson devised the idea of "hot spots" – magma that remains stationary under moving plates – to account for the formation of volcanic chains like the Hawaiian Islands. He also developed the concept of transform faults to explain phenomena like the San Andreas Fault. Explore the significance of these contributions to the study of plate tectonics.

Sample questions: What contributions have Canadian scientists made to the study of sediment and glacial records, and how have these contributions increased our understanding of long-term changes in Earth systems? What role have Canadians played in the development or use of technological applications such as Radarsat, and how have these applications contributed to our knowledge of Earth systems?

D2. Developing Skills of Investigation and Communication

By the end of this course, students will:

D2.1 use appropriate terminology related to Earth and its geological history, including, but not limited to: *Milankovitch cycles, era, epoch, period, parent isotope, hot spot, paleomagnetism*, and *index fossil* [C]

D2.2 use a research process to investigate the geological history of an area in Ontario (e.g., use a sequence diagram, geological maps showing main geological units or associated rock types, and/or surficial/bedrock geology maps to investigate the Oak Ridges Moraine or Niagara Escarpment) [IP, PR]

D2.3 investigate various types of preserved geological evidence of major changes that have taken place in Earth history (e.g., fossil evidence of mass extinctions, topographic evidence of past glaciations, evidence of plate movement in igneous rocks with magnetic reversals) [PR]

D2.4 produce a model or diagram to illustrate how geological time scales compare to human time scales (e.g., major events in Earth's geological history or the geological history of their region compared to major events in human history or students' own lifespans) [PR, C]

D2.5 produce diagrams to illustrate the development of various types of unconformities preserved in a sequence of strata (e.g., angular unconformity, disconformity, nonconformity) [PR, C]

D2.6 design and build a model to represent radioactive decay and the concept of half-life determination [IP, PR]

D2.7 investigate interactions over time between physical, chemical, and biological processes, and explain how they have affected environmental conditions throughout Earth's geological history (e.g., the impact of increasing amounts of atmospheric oxygen on stromatolites; the impact of increasing amounts of atmospheric carbon dioxide on global warming; the influence of plants on the water cycle, other life forms, the atmosphere, weathering, and erosion) [PR, AI, C]

D3. Understanding Basic Concepts

By the end of this course, students will:

D3.1 describe evidence for the evolution of life through the Proterozoic, Paleozoic, Mesozoic, and Cenozoic eras, using important groups of fossils that date from each era (e.g., stromatolites, trilobites, brachiopods, crinoids, fish, angiosperms, gymnosperms, dinosaurs, mammals)

D3.2 describe various kinds of evidence that life forms, climate, continental positions, and Earth's crust have changed over time (e.g., evidence of mass extinction, of past glaciations, of the existence of Pangaea and Gondwanaland)

D3.3 describe some processes by which fossils are produced and/or preserved (e.g., original preservation, carbonization, replacement, permineralization, mould and cast formations)

D3.4 compare and contrast relative and absolute dating principles and techniques as they apply to natural systems (e.g., the law of superposition; the law of cross-cutting relationships; varve counts; carbon-14 or uranium-lead dating)

D3.5 identify and describe the various methods of isotopic age determination, giving for each the name of the isotope, its half-life, its effective dating range, and some of the materials that it can be used to date (e.g., uranium-lead dating of rocks; carbon dating of organic materials)

D3.6 explain the influence of paradigm shifts (e.g., from uniformitarianism to catastrophism) in the development of geological thinking

D3.7 explain the different types of evidence used to determine the age of Earth (e.g., index fossils; evidence provided by radiometric dating of geological materials or lithostratigraphy) and how this evidence has influenced our understanding of the age of the planet

E. EARTH MATERIALS

OVERALL EXPECTATIONS

By the end of this course, students will:

E1. analyse technologies used to explore for and extract Earth materials, and assess the economic and environmental impact of the exploitation of such materials;

E2. investigate the properties of minerals and characteristics of rocks, including those in their local area;

E3. demonstrate an understanding of the properties of minerals and the formation and characteristics of rocks.

SPECIFIC EXPECTATIONS

E1. Relating Science to Technology, Society, and the Environment

By the end of this course, students will:

E1.1 assess the direct and indirect impact on local, provincial/regional, or national economies of the exploration for and extraction and refinement/processing of Earth materials (e.g., gold, uranium, sand, gravel, dimension stone, fossil fuels) [AI, C]

Sample issue: Diamonds are prized for industrial and personal uses. The demand contributes to the existence of illegal trade in "blood diamonds", in which stones mined in war zones are sold and the revenue is used to fund military action by insurgent groups. The protracted wars devastate local and national economies.

Sample questions: What are the effects on local economies of oil extraction in Alberta, transportation by pipeline through the Prairies, and refinement in Ontario? How does the economic benefit of manufacturing items using a mineral resource compare to the economic benefits for the communities that mine the resource? What is the impact on the economy of local Aboriginal communities of diamond mining on their lands?

E1.2 analyse technologies and techniques used to explore for and extract natural resources, and assess their actual or potential environmental repercussions [AI, C]

Sample issue: Mountaintop removal is a coal-mining technique proposed for use near the headwaters of the Flathead River in British Columbia. Mining companies favour the technique because the coal can be removed more cheaply than in conventional mining. However, the process devastates the local environment, causing erosion, loss of terrestrial and aquatic habitat, and air and water pollution.

Sample questions: Why has there been so much protest against the proposed Mackenzie Valley pipeline in the Canadian North? What mining techniques have the greatest and the least impact on local water systems? How are assessments of the permeability and porosity of rock structures used to determine the location of fossil fuels? What impact has the extraction of oil from the Alberta oil sands had on the local environment?

E2. Developing Skills of Investigation and Communication

By the end of this course, students will:

E2.1 use appropriate terminology related to Earth materials, including, but not limited to: *geothermal vents*, *porosity*, *permeability*, *cleavage*, *fracture*, *cementation*, *evaporite*, and *foliation* [C]

E2.2 investigate the properties of various Earth materials (e.g., density, conductivity, porosity; whether they are magnetic or radioactive), and explain how these properties affect how the materials are used and what technologies and techniques are used to explore for or extract them (e.g., radiometric instruments, electromagnetic or gravity surveys) [PR, AI, C]

E2.3 conduct a series of tests (e.g., hardness, streak, density) to identify and classify common minerals (e.g., quartz, calcite, potassium feldspar, plagioclase feldspar, muscovite, biotite, talc, graphite, hornblende) [PR, AI]

E2.4 investigate common igneous rocks (e.g., granite, obsidian, andesite, basalt, gabbro), using a hand lens, classify them on the basis of their texture (e.g., porphyritic, phaneritic, aphanitic) and composition (e.g., acid, intermediate, basic), and use this information to determine their origins (i.e., extrusive or intrusive) [PR, AI]

E2.5 investigate sedimentary rocks (e.g., conglomerate, breccia, sandstone, shale, limestone, dolostone, chert, gypsum, rock salt, coal), using a hand lens, classify them on the basis of their texture (e.g., coarse- or fine-grained, detrital) and composition (e.g., clastic, chemical, fossil inclusions), and use this information to determine their origin (e.g., clastic, chemical) [PR, AI]

E2.6 investigate metamorphic rocks (e.g., slate, phyllite, schist, gneiss, quartzite, marble), using a hand lens, and classify them on the basis of their characteristics (e.g., foliation, crystallinity) in order to identify their parent rock and the temperature, pressure, and chemical conditions at their formation [PR, AI]

E2.7 investigate a geological setting in their local area (e.g., a river/stream bed or lakeshore; a rock outcrop), and identify and classify rock samples collected from that area [PR, AI]

E2.8 plan and conduct an inquiry to investigate the factors that determine the size and form of mineral crystals (e.g., the temperature of the solution, the type of salt, the level of saturation, the temperature of slides containing melted salol) [IP, PR]

E3. Understanding Basic Concepts

By the end of this course, students will:

E3.1 identify the physical and chemical properties of selected minerals, and describe the tests used to determine these properties

E3.2 describe the formation (i.e., intrusive or extrusive) and identify the distinguishing characteristics of igneous rocks (e.g., composition and eruption type; mineralogical content indicating the type of volcano in which a rock was formed)

E3.3 describe the formation of clastic and chemical sediments, and the characteristics of the corresponding sedimentary rocks (e.g., shape and size of particles, nature of their deposition)

E3.4 describe the different ways in which metamorphic rocks are formed (i.e., through changes in temperature, pressure, and chemical conditions) and the factors that contribute to their variety (e.g., variation in parent rock; regional or contact metamorphism)

E3.5 describe the role of Earth materials in the safe disposal of industrial and urban waste and toxic materials (e.g., the low permeability of clays makes them suitable material for barriers in waste disposal sites)

F. GEOLOGICAL PROCESSES

OVERALL EXPECTATIONS

By the end of this course, students will:

F1. analyse technological developments that have increased our knowledge of geological processes and structures, and how this knowledge assists in monitoring and managing these processes and structures;

F2. investigate, through the use of models and analysis of information gathered from various sources, the nature of internal and surficial Earth processes, and the ways in which these processes can be quantified;

F3. demonstrate an understanding of the processes at work within Earth and on its surface, and the role of these processes in shaping Earth's surface.

SPECIFIC EXPECTATIONS

F1. Relating Science to Technology, Society, and the Environment

By the end of this course, students will:

F1.1 evaluate the accuracy and reliability of technological methods of monitoring and predicting earthquakes, tsunamis, and volcanic eruptions [AI, C]

Sample issue: In the past, seismometers used a pendulum attached to a stylus to detect anomalies in the movement of Earth's surface. Modern seismometers use electronic sensors and amplifiers. These seismographic systems are located worldwide, allowing scientists to predict the timing and location of earthquakes with increased accuracy.

Sample questions: What new technologies have been developed to monitor tsunamis since the devastating tsunami in the Indian Ocean in December 2004? How accurately can scientists predict major volcanic eruptions? How accurate are various technologies used to predict earthquakes?

F1.2 analyse developments in technology (e.g., sonar, seismology, magnetometers) or Earth science endeavours (e.g., Lithoprobe, Geosat, Ocean Drilling Program) that have contributed to our understanding of Earth's interior, crust, and surface [AI, C]

Sample issue: Magnetometers have developed from bulky land-based machines to sensitive, satellite-mounted devices that survey vast areas. Magnetometers provide information on underground rock formations, on the location of resources such as fossil fuels and iron ore, on anomalies in Earth's crust, and on the movement of land masses.

Sample questions: How can the global positioning system (GPS) be used to gather information on plate movements? What is the Lithoprobe project, and how has it enhanced our knowledge of Earth's interior? How are seismographs used to detect water below Earth's surface?

F1.3 analyse the relationship between human activities and various geological structures and processes (e.g., the relationship between the location of deposits and the extraction/use of resources; the relationship between urban development and/or building codes and the probability of earthquakes or volcanic activity), and propose ways in which the relationships can be effectively or sustainably managed [AI, C]

Sample issue: Volcanic eruptions can be destructive and deadly. However, because volcanic soil is rich and fertile, it is valued as farmland, and farms, towns, and even cities have developed near volcanoes. Constant monitoring of volcanic activity and development of evacuation plans are necessary to reduce the risk for human habitations near a volcano.

Sample questions: What impact do stream erosion and alluvial deposits have on agriculture along a river? What are some ways in which humans can exploit mineral resources without depleting them or harming the environment? What negative effects can construction projects have on surface water or groundwater systems? How can these effects be reduced?

F2. Developing Skills of Investigation and Communication

By the end of this course, students will:

F2.1 use appropriate terminology related to geological processes, including, but not limited to: *shear forces, compression forces, liquifaction, Benioff zone, aquifer, internal plastic flow, basal slip, mid-oceanic ridge, bedding, cross-cutting, isostasy,* and *lithification* [C]

F2.2 investigate the difference between weathering and erosion (e.g., weathering occurs when the edge of a riverbank disintegrates from the force of the water; erosion occurs when the water transports the soil downstream), and construct models of the processes of physical, chemical, and biological weathering (e.g., tap water dripping on a bar of soap; vinegar dripping on a marble chip; dried beans soaking in a sealed plastic jar) [PR]

F2.3 produce a model showing simple sedimentary sequences (e.g., successive layering, sorted sequences), using block diagrams or three-dimensional models (e.g., layering as sand settles in an aquarium) [PR, C]

F2.4 investigate, through laboratory inquiry or computer simulation, the main types of seismic waves, and produce a model (e.g., using 3D block diagrams or springs and ropes) to illustrate for each the nature of its propagation, the transfer of energy, and its movement through rocks [PR, C]

F2.5 locate the epicentre of an earthquake, given the appropriate seismographic data (e.g., the travel-time curves to three recording stations for a single event) [AI]

F2.6 produce a scale model (e.g., a 3D block diagram) of the interior of Earth, differentiating between the layers and their characteristics (e.g., label cross-sections with the dimensions of the crust, mantle, and inner and outer core, and add travel-time curves for various seismic waves to provide data on the characteristics of the individual layers) [PR, C]

F2.7 design and test models that show the types (i.e., falls, slides, or flows) and causes (e.g., effect of gravity [angle of repose], water content, earthquakes) of mass wasting [IP, PR, AI]

F2.8 analyse information from a plan view (e.g., topographic map, air photo, geologic map) and sectional view (e.g., cross section, block diagram) in order to deduce the geologic history of an area [AI]

F3. Understanding Basic Concepts

By the end of this course, students will:

F3.1 describe the types of boundaries (convergent, divergent, transform) between lithospheric plates, and explain the types of internal Earth processes occurring at each (e.g., subduction, divergence, convergence, hot spot activity, folding, faulting)

F3.2 describe the characteristics of the main types of seismic waves (i.e., P- and S-waves; R- and L-waves), and explain the different modes of travel, travel times, and types of motion associated with each

F3.3 compare qualitative and quantitative methods used to measure earthquake intensity and magnitude (e.g., the Mercalli Scale, the Richter Scale)

F3.4 explain how different erosional processes contribute to changing landscapes (e.g., channel erosion, mass-wasting events)

F3.5 identify and describe types of sediment transport (e.g., water, wind, glacial) and the types of load (i.e., dissolved load, suspended load, bed load) as sediment is moved by each type of transport

F3.6 describe the landforms produced by water, wind, or ice erosion

F3.7 describe the sedimentary structures formed by wind, water, or ice deposition

F3.8 identify major areas of tectonic activity in the world by plotting the location of major recorded earthquakes and active volcanoes on a map, and distinguish the areas by type of tectonic activity (e.g., Japan – convergent boundary; Iceland – divergent boundary; California – transform boundary)

F3.9 explain the processes of continuous recycling of major rock types (i.e., the rock cycle) throughout Earth history