Science standards

Grade 10

Advanced level

Summary of students' performance by the end of Grade 10

Scientific enquiry

Students identify, develop, and make predictions related to a clearly focused research question. They control variables, work as a team and use appropriate equipment and materials. They evaluate experimental design, identify weaknesses and develop realistic strategies for improvement, and work in an ethical manner. Students know how scientists disseminate their ideas, understand the historical development of major ideas and balance the opportunities of science against its environmental threats. They record and process raw data appropriately and draw valid conclusions allowing for errors and uncertainties. They handle equipment competently with due regard to safety. They follow instructions accurately but are able adapt to unforeseen circumstances.

Biology

Students know the composition and structure of glucose, amino acids, glycerol, fatty acids, triglycerides, phospholipids, chlorophyll and haemoglobin. They know that monosaccharides and amino acids are the monomers of other carbohydrates and proteins, respectively. They describe the primary, secondary and tertiary structure of proteins. They understand the relationship between the structure and the function and properties of biological molecules. They recognise test results for protein, sugar and starch, and know the purpose of chromatography and electrophoresis. They know the structure of prokaryote and eukaryote cells. They recognise various parts of a cell and know their functions. They know how the electron microscope and ultracentrifuge have aided the study of cell ultrastructure. They recall that enzymes are proteins and are biological catalysts. They explain enzyme action as a substrate–enzyme complex reaction. They know that enzymes lower the activation energy for a reaction and that their function depends on their structure. They distinguish between competitive and non-competitive enzyme inhibition. They explain the effects of changes of temperature, pH and substrate concentration on enzyme action and relate these to structure. They explain why multicellular animals need a transport system for respiratory gases, water, food and waste, and describe the structure and function of the human circulatory system. They classify diseases and illnesses into different types and distinguish between endemic, epidemic and pandemic diseases. They know what constitutes a balanced diet and the energy and nutrient requirements for different lifestyles. They know why an inappropriate diet can lead to malnutrition, anorexia or obesity. They link poor diet to coronary heart disease and diabetes. They know the double-helix structure of DNA and how this replicates. They know the role of DNA, mRNA and tRNA in protein synthesis. They understand how the base sequence on DNA controls the structure and function of a protein. They know that the base sequence on DNA forms the inherited genetic code. They know the structure and function

of chromosomes and that chromosomes carry DNA. They know that somatic cells have the diploid (2*n*) number of chromosomes and gametes the haploid number (*n*). They know that sexual reproduction is a mechanism for passing genetic material from one generation to another. They understand why male and female gametes differ in size, number and motility. They identify causes of variation within populations and distinguish between continuous and discontinuous variation. They know that species are clustered into groups. They know about the hierarchy of classification and the key features of the kingdoms and main phyla of animals and plants. They understand how energy flows through an ecosystem. They relate pyramids of numbers, biomass and energy to food chains and food webs. They know the roles of micro-organisms in recycling and how they function in the carbon and nitrogen cycles. They know that the nitrogen-fixing micro-organisms in root nodules have a mutualistic relationship with the host plant.

Chemistry

Students know the distribution of mass and charge in atoms and ions up to element 56, show how electronic structure explains the pattern of elements in the periodic table and manipulate quantities such as proton number and mass number. They understand ionic, covalent and metallic bonding and explain the properties, including allotropy, of elements and compounds in terms of bond types. They write balanced molecular and ionic equations for simple reactions. They explain the macro-properties of the different states of matter in terms of their micro-structure. They know a variety of processes by which useful substances are made from raw materials, including alkalis, chlorine and useful metals. They know that the extractive industries can cause environmental degradation and understand a variety of ways this can be minimised. Students recognise periodicity in the properties of elements and their compounds, with particular reference to elements of groups I, II, VII and VIII and the first transition series. They know the origins of metallic properties, how these can be modified by alloying, and that metals vary in reactivity in a manner related to their position in the periodic table. They distinguish between strong and weak acids and alkalis, perform neutralisation titrations, make salts and know how the basicity of the oxides changes across the third period of the periodic table. They know the properties of the main constituents of air and understand how carbon, nitrogen and water are recycled in nature and that many of our activities interfere with these processes. They know the main atmospheric pollutants and many of their effects. They understand the importance of not polluting water courses and know the processes by which potable water is made. They understand the processes by which run-off enriched in nutrients can cause water sources, including the sea, to become depleted in oxygen and life. Students know the factors that affect reaction rate and explain them in terms of the particle model and they understand the concept of dynamic equilibrium. They understand the energy profile of a reaction and know how catalysts work by altering it. They know and use the concepts of enthalpy of reaction and activation energy and associate endothermic and exothermic changes with bond breaking and making.

Physics

Students are familiar with fundamental and derived SI units, and use appropriate prefixes for small and large measurements. They handle inaccuracies and uncertainties when taking and manipulating measurements and distinguish between vector and scalar quantities. They

understand, manipulate and represent graphically the concepts of displacement, speed, velocity and acceleration to solve problems related to moving objects. They know that a force can cause a change in velocity or shape of an object, resolve multiple forces acting on an object and distinguish between dynamic and static friction. They explain observations such as expansion, freezing, melting, boiling, evaporation, crystallisation, the Brownian motion and fluid pressure in terms of particle interactions. They have knowledge of the anomalous expansion of water and its importance. They understand density, flotation and pressure in solids and fluids, which they apply to hydraulics and pneumatics. They define and measure temperature and know why and how thermal energy moves from place to place. Students know that energy is transferred in the form of pulses and waves, and understand and manipulate the measurable parameters associated with waves. They know that sound is a waveform that requires a medium, they measure its speed in air and know how the ear detects sounds. They know that light travels in straight lines and how it is reflected and refracted; they are aware of some of the applications of these properties. They understand dispersion and recognise some of its natural consequences, and know how the eye receives and focuses light. Students generate electrostatic charge in insulators, know the rules of electrostatic attraction, know how to use an electroscope to investigate charge and understand distribution of charge on a conductor. They detect electric fields and know that they can exert a force on a conductor. They know that magnets have north and south poles and generate fields, the shape of which they plot, that exert forces on other magnets and on wires carrying a current. Students know that an electric current is a stream of charged particles and solve problems related to charge, current, potential difference and resistance.

Assessment weightings for Grade 10

There are three general assessment objectives for the science curriculum:

- knowledge and understanding;
- application of knowledge and understanding, analysis and evaluation of information;
- scientific enquiry skills and procedures.

The science standards for Grade 10, advanced level, are grouped into four strands: three subject content strands – biology, chemistry and physics – and the scientific enquiry skills strand, which addresses the development of scientific practical and intellectual skills across all the content strands. The teaching and the assessment of the scientific enquiry skills strand should be carried out as an integral part of the teaching of the content strands.

For Grade 10, advanced level, each of the three subject content strands – biology, chemistry and physics – carries an equal weighting.

For Grade 10, advanced level, the weightings of the assessment objectives to be applied to each content strand are as follows:

	Knowledge and understanding	Application, analysis and evaluation	Scientific enquiry skills and procedures
Assessment weighting	45 to 55%	25 to 35%	20 to 25%

Science standards

Grade 10

Advanced level

Scientific enquiry

Key standards

Key standards are shown in shaded rectangles, e.g. 1.3.

Examples of learning exercises

The examples of active learning exercises shown in italics are intended to be illustrative and do not represent the full range of possible exercises.

By the end of Grade 10, students identify, develop, and make predictions related to a clearly focused research question. They control variables, work as a team and use appropriate equipment and materials. They evaluate experimental design, identify weaknesses and develop realistic strategies for improvement, and work in an ethical manner. Students know how scientists disseminate their ideas, understand the historical development of major ideas and balance the opportunities of science against its environmental threats. They record and process raw data appropriately and draw valid conclusions allowing for errors and uncertainties. They handle equipment competently with due regard to safety. They follow instructions accurately but are able adapt to unforeseen circumstances.

Students should:

1 Use methods of scientific investigation

1.1 Identify and develop a clearly focused research question.

Investigate the effect of pH on rate of enzyme action.

Investigate variability of height and foot size and links between them.

Investigate particulate deposition from the atmosphere.

Determine the acceleration due to gravity.

Devise a way of comparing the hardness of aluminium with the hardness of some of its alloys.

1.2 Make predictions directly related to a research question.

Predict the structure of biological molecules from their properties.

Predict the properties of a metal from its position in the reactivity series.

Predict the characteristic properties of an element based on its position in the periodic table.

1.3 Identify and control variables.

Determine the effect of temperature on enzyme action.

Determine factors affecting rates of reaction.

1.4 Work constructively and adaptively with others as a team on a scientific investigation.

Determine trends in national statistics medical disorders.

1.5 Evaluate experimental design, identify weaknesses and develop realistic strategies for improvement.

Design and evaluate an experiment to determine the constituents of foodstuffs.

Compare the influence of pH and temperature on enzyme action.

Minimise heat losses during the measurement of heat lost or gained during a reaction.

Assess accuracy and precision when making physical measurements.

Improve the accuracy of the measurement of the acceleration due to gravity.

Make and test a model thermostat from a bimetallic strip.

Make and test an electric motor.

1.6 Work in an ethical manner with regard to acknowledging data sources and authenticity of results.

Report on library and Internet studies with due acknowledgement to the original author.

1.7 Work in an ethical manner with regard to living things and the environment.

Minimise environmental damage during field excursions.

1.8 Identify, and make critical use of, secondary information.

Use WHO sources to determine incidences of diseases in various regions of the world.

Study the changes in atmospheric carbon dioxide concentration and mean Earth surface temperature over time.

2 Know how scientists work

2.1 Understand the historical development of the major scientific ideas.

Study the historical development of the understanding of micro-organisms.

Role-play situations to illustrate changing conceptions of disease.

Chart the changes in the techniques used to extract metals from their ores from earliest times to the present day.

Show how empirical work on the classification of elements by Mendeleev was later explained by the electronic structure of the elements.

2.2 Know how scientists disseminate their ideas and results to encourage discussion and further development.

Download from the Internet, and study, key original papers (e.g. the papers by Rutherford and others on alpha particle scattering and by Watson and Crick on the structure of DNA).

Hold a class conference to share and discuss experimental results.

Check the news for reports of advances in science.

2.3 Know that science can bring great advantages to humanity but can also cause considerable damage to the environment.

Discuss the role of the carbon cycle in relation to the generation of carbon dioxide by industrial processes.

Debate the benefits and the environmental impact of some of the industrial processes covered in section 17, particularly those that are established in Qatar.

Discuss the threats to the environment posed by our frequent disposal of waste gases into the atmosphere, as noted in section 21.

3 Process and communicate information

3.1 Record raw data appropriately in a manner that allows easy interpretation.

Produce charts to show the results of tests on foodstuffs.

Tabulate results of comparative experiments down groups and across periods in the periodic table.

Show the difference between several ohmic and non-ohmic conductors graphically on the same V/I graph.

3.2 Process raw data by the most appropriate means.

Calculate the mean and range of the hand spans of students of different age.

Show graphically the pH change during neutralisation.

Process graphically data on velocity and acceleration.

3.3 Draw valid conclusions, allowing for errors and uncertainties.

From experimental testing of samples of DNA decide which matches a given profile.

Arrange metals in order of reactivity based on experimental results.

3.4 Use an appropriate range of methods to communicate scientific information.

Produce wall charts to illustrate the replication of DNA.

Create a radio documentary on the nitrogen cycle.

Use ICT to create displays of dynamic processes (e.g. electron migration during a chemical reaction).

Make models to show complex three-dimensional molecular structures (e.g. diamond, graphite and fullerene).

Use flow charts to summarise industrial and biological processes.

4 Handle equipment and make measurements

4.1 Select and use correctly and competently the appropriate equipment and materials for an investigation, with due regard for the safety of self and others.

Use an appropriate microscope and magnification to study cells and cell structures.

Use chromatography and electrophoresis apparatus.

Use an oscilloscope to study sound waves.

Use optical equipment safely.

4.2 Follow instructions accurately but be able to adapt to unforeseen circumstances.

Biology

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Students should:

5 Describe the composition and molecular structure of some biologically important molecules

5.1 Describe the composition and molecular structure of glucose, amino acids, glycerol, fatty acids, triglycerides, phospholipids, chlorophyll and haemoglobin.

Study three-dimensional molecular models.

Make simple molecular models.

5.2 Recognise that monosaccharides and amino acids are monomers for other carbohydrates (e.g. starch and cellulose) and proteins (e.g. enzymes), respectively.

Carry out chemical tests for carbohydrates.

Separate amino acids by chromatography.

5.3 Describe the primary, secondary and tertiary structure of proteins.

Study three-dimensional molecular models.

6 Relate the properties of some biologically important molecules to their size and structure

6.1 Know that smaller molecules are soluble, can be transported and are mostly involved in metabolism, while large molecules tend to have storage (e.g. starch), structural (e.g. cellulose) and informational (e.g. DNA) roles.

Determine the solubility of compounds with large and small molecules.

Given the relative size of molecules, carry out matching exercises to relate molecules to functions.

6.2 Recognise the results of tests for proteins, sugars and starch.

Carry out standard tests for proteins, sugars and starch.

Identify biological molecules from electrophoresis and/or chromatography data.

6.3 Know that biological molecules can be separated and identified by chromatography and electrophoresis.

Use chromatography and electrophoresis to separate mixtures of compounds.

Identify biological molecules from electrophoresis and/or chromatography data.

7 Recognise features of cell ultrastructure and know their functions

7.1 Differentiate between prokaryotic and eukaryotic cells.

Examine cells with a microscope.

Analyse photomicrographs of cells.

7.2 Recognise and know the function of a nucleus, mitochondria, chloroplasts, endoplasmic reticulum and ribosomes.

Using information cards, match electron microscope pictures of cell structures to their function.

Study electron micrographs of cell structures and write descriptions.

Make scale models of cell organelles.

7.3 Know how the electron microscope and the ultracentrifuge have contributed to our knowledge of cell ultrastructure.

Make a visit to see an electron microscope and/or an ultracentrifuge.

Use the Internet to learn how an electron microscope works.

Construct a model to show the difference between the magnification of a light microscope and an electron microscope.

ICT opportunity

Use the Internet to gather information.

8 Explain enzyme action

8.1 Know that enzymes are globular proteins that act as biological catalysts; explain how they operate by forming a substrate–enzyme complex on an active site so lowering the activation energy for a reaction.

Construct physical models of enzyme action.

8.2 Explain how the structure of an enzyme leads to its substrate specificity.

Use card to create simple two-dimensional models of enzymes and substrates. Allocate cards to different students. Get students to match enzymes and substrates.

8.3 Differentiate between the mechanisms of competitive and non-competitive inhibition of enzyme action.

Construct diagrammatic representations of enzyme inhibition.

8.4 Describe and explain why changes of temperature, pH and substrate concentration affect the rate of enzyme action.

Investigate the rate of catalase reaction with hydrogen peroxide at different temperatures and plot a graph of the oxygen released.

9 Know about the human blood system as an example of a transport system in a multicellular animal

9.1 Explain why large animals need transport systems for respiratory gases, water, food and waste in terms of their surface to volume ratio.

Construct cubes of different sizes and calculate their surface to volume ratios.

Investigate the time taken for a drop of coloured dye to diffuse completely in different volumes of water.

9.2 Describe the external and internal structure of the heart. Relate features to functions in pumping blood round the body and maintaining separation of oxygenated and deoxygenated blood.

Dissect a heart or study a model.

Find out about artificial heart valves.

Watch and discuss a video of heart action.

ICT opportunity
Use video for illustration.

9.3 Know how the heartbeat is initiated and maintained, and describe the cardiac cycle.

Measure heart rate.

Study charts of heart rate.

Use the library and the Internet to find out how a heart pacemaker works.

ICT opportunity
Use the Internet to gather information.

9.4 Know that the human blood system is a double closed system and know the names, locations and roles of the major blood vessels.

Study charts of the human blood system.

Play a card game in which the names of blood vessels have to be matched with the organs they are attached to.

Use the library and the Internet to investigate claims for the first description of the human blood system.

ICT opportunity
Use the Internet to gather information.

9.5 Differentiate between arteries, veins and capillaries in terms of wall thickness and valves, and relate their structure to their function.

Use a microscope to observe and draw cross-sections through arteries, veins and capillaries.

9.6 Know that red blood cells carry oxygen.

Use a microscope to observe and draw red blood cells.

Use a video clip to observe the changes in colour of oxygenated and deoxygenated blood.

ICT opportunity
Use video for illustration.

10 Know about some aspects of human health, illness and disease

10.1 Classify diseases or illnesses as physical, mental, social, infectious, non-infectious, degenerative, inherited or deficiency.

Make a wall display of types of diseases and illnesses.

10.2 Distinguish between endemic, epidemic and pandemic diseases.

Each student selects a country as a possible holiday, study or work destination. They then use the library and the Internet to find out which diseases are endemic to that country and if it has recently had any disease epidemics.

ICT opportunity

Use the Internet to gather information.

10.3 Know what constitutes a balanced diet and how the nutrient balance and energy content of a diet should relate to the lifestyle of the consumer.

Prepare diet sheets for people of different age and occupation.

10.4 Know why an inappropriate diet can lead to anorexia, obesity, coronary heart disease or diabetes.

Form the class into teams and ask each to make contact with a different health-promoting organisation in Qatar. The class should work together to find out the trend of national statistics for anorexia, obesity, coronary heart disease and diabetes, and to discover what actions the health-promoting organisations are taking.

11 Know the importance of DNA

11.1 Describe the double-helix structure and semi-conservative replication of DNA, and recognise the importance of the base pairings.

Construct a simple model of DNA.

Use the library and /or the Internet to find out about work on the structure of DNA by Watson and Crick, and Franklin.

ICT opportunity

Use the Internet to gather information.

11.2 Describe the role of DNA, mRNA and tRNA in protein synthesis and understand how a base sequence on DNA controls the structure and function of a protein.

Role-play the construction of a protein from a base sequence on DNA.

11.3 Know that the base sequence on DNA forms the genetic code and is passed from generation to generation.

Make up a class mnemonic to help remember the base pairings of DNA.

12 Know the role of sexual reproduction and chromosomes in genetic inheritance

12.1 Describe a chromosome and know that chromosomes carry DNA and that all somatic cells are diploid ($2n$), and have a double set of chromosomes, while gametes are haploid (n), having a half set of chromosomes.

Use a microscope to observe and draw chromosomes.

Study photographs and drawings of chromosomes of different organisms.

Compare pictures or drawings of the chromosomes of somatic and sex cells.

Make model chromosomes.

12.2 Know that sexual reproduction allows genetic material to be passed from one generation to the next and understand why the sex cells of males and females differ in size, number and motility.

Use a microscope to compare prepared slides of sperm and egg cells.

13 Know about variation in populations

13.1 Identify environmental and genetic causes of variation and distinguish between continuous and discontinuous variation within a population.

Collect data on discrete and continuous variables for the class and display in graphical form.

Use a census database (e.g. for birds) and plot data for continuous and discrete variables.

Germinate seeds from the same seed packet. Plant out 10 seedlings into each of a number of separate containers. Place the containers in different conditions. Measure the growth of the seedlings over time. Determine which variations are due to genetics and which to environment.

ICT opportunity

Use a database for data extraction.

14 Understand how organisms are classified and know the key features of the major groups

14.1 Understand the term *species*, know that species can be placed in groups with shared features, and that the groupings of kingdom, phylum, class, order, genus and species form a hierarchy of classification.

Use keys to classify organisms.

14.2 Know the distinguishing features of the five kingdoms: Prokaryotae, Fungi, Protoctista, Plantae and Animalia.

Use specimens, models, photographs and drawings to illustrate examples of organisms from each of the kingdoms.

Make a wall display to illustrate the different kingdoms.

14.3 Use knowledge of the key features of the major phyla of animals and plants to recognise a typical member.

Use specimens, models, photographs and drawings to classify organisms.

Make a photographic record of local members of selected phyla.

15 Know about energy flow in an ecosystem

15.1 Describe how organisms in a pyramid of numbers relate to their biomass and to energy flow through food chains and food webs.

Construct pyramid diagrams to show species numbers and biomass in food chains and food webs.

15.2 Draw energy-flow diagrams to illustrate how energy flows through an ecosystem.

Obtain data on energy flow and use this to construct energy-flow diagrams for various ecosystems.

16 Know the importance of micro-organisms in recycling

16.1 Know that micro-organisms act as decomposers and help to recycle organic material.

Investigate the rate of decomposition of various organic and inorganic materials kept in different conditions.

16.2 Know the roles of micro-organisms in the different stages of the carbon and nitrogen cycles.

Shake up samples of different soil with water. Plate out a few drop of the liquids onto nutrient agar in Petri dishes and incubate. Observe the range and number of bacterial and fungal colonies in different soils.

Draw wall charts of the nitrogen and carbon cycles.

16.3 Know that nitrogen-fixing bacteria have a mutualistic relationship with the leguminous plants on which they form root nodules.

Observe and draw the roots and root nodules of leguminous plants.

Use a microscope to examine a cross-section of the root nodules of a leguminous plant.

See Standard 22.1

Safety

Plates should be sealed, incubated at no more than 30°C and destroyed after study.

Chemistry

By the end of Grade 10, students know the distribution of mass and charge in atoms and ions up to element 56, show how electronic structure explains the pattern of elements in the periodic table and manipulate quantities such as proton number and mass number. They understand ionic, covalent and metallic bonding and explain the properties, including allotropy, of elements and compounds in terms of bond types. They write balanced molecular and ionic equations for simple reactions. They explain the macro-properties of the different states of matter in terms of their micro-structure. They know a variety of processes by which useful substances are made from raw materials, including alkalis, chlorine and useful metals. They know that the extractive industries can cause environmental degradation and understand a variety of ways this can be minimised. Students recognise periodicity in the properties of elements and their compounds, with particular reference to elements of groups I, II, VII and VIII and the first transition series. They know the origins of metallic properties, how these can be modified by alloying, and that metals vary in reactivity in a manner related to their position in the periodic table. They distinguish between strong and weak acids and alkalis, perform neutralisation titrations, make salts and know how the basicity of the oxides changes across the third period of the periodic table. They know the properties of the main constituents of air and understand how carbon, nitrogen and water are recycled in nature and that many of our activities interfere with these processes. They know the main atmospheric pollutants and many of their effects. They understand the importance of not polluting water courses and know the processes by which potable water is made. They understand the processes by which run-off enriched in nutrients can cause water sources, including the sea, to become depleted in oxygen and life. Students know the factors that affect reaction rate and explain them in terms of the particle model and they understand the concept of dynamic equilibrium. They understand the energy profile of a reaction and know how catalysts work by altering it. They know and use the concepts of enthalpy of reaction and activation energy and associate endothermic and exothermic changes with bond breaking and making.

Students should:

17 Understand the structures of atoms and molecules and how these determine their physical and chemical properties

17.1 Describe the distribution of mass and charge within an atom and deduce the numbers of protons, neutrons and electrons present in both atoms and ions, given proton and nucleon numbers.

Study and interpret the Rutherford experiment, in which gold foil is bombarded with a beam of alpha particles. Invite the students to interpret the results of the experiment as though they were scientists alive at the time.

17.2 Deduce the atomic structure of an atom or ion of any given element up to barium (56) and show how the structures explain the pattern of elements in the periodic table.

Make a display showing the full atomic structures of the first 20 (or 56) elements. This can be done as an ICT exercise in HTML with the structure and a picture of a sample of the element displayed in a link.

ICT opportunity

Use HTML.

Downloading images from the Internet.

Make a flow chart showing the development of atomic theory from ancient times to Schrödinger.

17.3 Define the terms *relative isotopic mass*, *relative atomic mass*, *relative molecular mass* and *relative formula mass* based on the carbon-12 scale and be able to calculate the relative molecular mass of a compound, given its formula and a relative atomic mass table.

Calculate relative molecular masses of a variety of compounds from atomic mass tables.

17.4 Know that mass spectrometry can furnish information on relative isotopic masses and isotopic abundance.

17.5 Know that isotopes can be distinguished by their different numbers of neutrons and explain why the relative atomic mass of many elements is not a whole number.

Make a display showing the structure of some well-known isotopes (e.g. chlorine-35 and chlorine-37).

Calculate the isotopic abundance of chlorine from its observed relative atomic mass.

Make models of nuclei of different isotopes of the same element from polystyrene balls with pins stuck in them.

17.6 Describe ionic (electrovalent) and covalent bonding.

Use Lewis ('dot and cross') diagrams to show bonding in a variety of common compounds (e.g. ionic bonding in sodium chloride, magnesium oxide, calcium chloride; covalent bonding in hydrogen, oxygen, water, hydrogen chloride, carbon dioxide, methane).

Design and make a display, using moveable valency electrons, to show bonding.

Make a dynamic ICT display (using a package such as PowerPoint) to show electron migration as bonds are formed.

ICT opportunity

Use dynamic graphics.

17.7 Explain metallic bonding in terms of a lattice of positive ions surrounded by a sea of mobile electrons and explain the physical properties of metals and alloys in terms of this bonding.

17.8 Know that some covalent compounds, such as the element carbon and the compound silicon(IV) oxide, form giant molecular structures.

Make models of the structures of diamond, graphite, fullerene and silica.

17.9 Show an understanding of allotropy.

Study allotropy in a number of common elements (e.g. carbon, sulfur, tin); draw structures of the different allotropes and compare their physical properties.

Show that graphite conducts electricity and explain this in terms of molecular structure.

Study three-dimensional models or rotatable applets of the structure of graphite, diamond and fullerene, and relate these structures to the properties of the allotropes.

Prepare samples of rhombic and monoclinic sulfur.

Safety

Use methylbenzene, not carbon disulfide (carcinogen and flammable) as the solvent from which to crystallise rhombic sulfur.

White phosphorus should only be handled by an appropriately trained teacher.

Study the difference in physical properties and reactivity between the red and white allotropes of phosphorus.

17.10 Explain the differing physical properties of covalent and ionic compounds in terms of their bonding and be able to deduce the type of bond from information about physical properties.

Show, using models or an overhead projector, such phenomena as crystal cleavage, gas molecule movement and giant structures, and explain how these molecular considerations explain macro-properties.

17.11 Explain why molten ionic compounds and solutions of ionic compounds conduct electricity.

Electrolyse a variety of solutions to show that only aqueous solutions of ionic compounds conduct electricity well. Demonstrate the electrolysis of a low-melting ionic solid (e.g. lead bromide).

Safety

Bromine is poisonous, use a fume cupboard.

Demonstrate the movement of coloured ions during electrolysis.

17.12 Write equations with state symbols for simple reactions, including ionic equations for reactions in aqueous solution, given the formulae of reactants and products.

Make a display showing how all the atoms move during a chemical reaction so that the need for balancing an equation is illustrated clearly.

ICT opportunity

Draw and manipulate models.

17.13 Use the kinetic particle theory to explain the main characteristics of the three states of matter and changes between the states:

- the basic assumptions of the kinetic theory as applied to an ideal gas;
- the liquid state, including melting, vaporisation and vapour pressure;
- the lattice structure of a crystalline solid.

Demonstrate particle behaviour during phase changes using models and Java applets. Show macro-properties of particle interactions (e.g. floating a razor blade on water, cleaving a quartz crystal, Brownian motion in smoke particles).

Discuss exceptions to the model such as glass which behaves like a solid but has the structure of a liquid.

17.14 Explain the strength, high melting point and electrical insulating properties of ceramics in terms of their giant molecular structure and relate these properties to their uses.

Tabulate some important uses of ceramics (e.g. furnace linings, Space Shuttle heat tiles, electrical insulators).

ICT opportunity

Find out about uses of ceramics from the Internet.

17.15 Know the commercial and industrial importance of composite materials that combine the properties of their constituents, and give examples

Make an illustrated display (possibly using display software) of the use of composites, showing how the properties of the constituents are used. Refer not only to composites that involve different solid structures but also to those that incorporate materials in different phases (e.g. insulating materials that contain trapped gases).

ICT opportunity

Use display software.

18 Understand the principles behind some of the industrial processes that we use to obtain pure chemicals

18.1 Know how purification techniques such as filtration, evaporation, distillation, fractionation and chromatography are used to obtain pure compounds from mixtures.

Revise the practical purification methods carried out in earlier grades and match them to purification techniques used in the chemical industry in Qatar.

Industrial visits

Study industrial techniques of purification.

18.2 Know the properties and uses of the main gases of air; describe and understand the process of fractionation of liquid air to produce pure gases.

Prepare a flow chart showing the stages of the fractionation of air.

18.3 Know how a variety of fuels and other useful compounds can be obtained from petroleum and natural gas.

Prepare a flow chart showing the different fractions obtained in an oil refinery and the main uses of each fraction.

Demonstrate the fractionation of crude oil and the physical properties and combustion characteristics of each fraction.

Safety

Fire risk. Have a working extinguisher to hand.

Visit the plant and study the process by which liquid fuel is made from natural gas in Qatar.

18.4 Know what is meant by hardness in water and how it is produced naturally. Distinguish between temporary and permanent hardness.

Test samples of water with soap to determine hardness. Distinguish between temporarily hard and permanently hard water. Characterise the water in the Doha supply.

Study how and why the distilled water from the sea in Qatar is processed to make it harder.

18.5 Explain, including the electrode reactions, industrial electrolytic processes such as:

- the electrolysis of brine using a diaphragm cell;
- the extraction of aluminium from molten aluminium oxide in cryolite;
- the electrolytic purification of copper.

Produce flow charts outlining each process illustrated with photographs downloaded from the Internet. Visit the aluminium smelter at Ras Laffan when it is operational.

ICT opportunity

Use the Internet as an information source on industrial processes.

18.6 Know the industrial importance of the halogens and their compounds as in, for example, the manufacture of bleaches, PVC, halogenated hydrocarbons as solvents and refrigerants, and insecticides, and be aware of the main environmental hazards associated with these uses.

List the industrial uses of chlorine in Qatar and study the processes put in place to minimise environmental impact.

18.7 Describe, with essential chemical reactions, the extraction of steel from iron ore and recycled scrap iron in the electric arc furnace.

Produce a flow chart of the process of the electric arc furnace, including the reasons for adding limestone. List the reactions that take place in the furnace.

Visit the steelworks in Qatar.

Chart the changes in the techniques for extracting iron from its ore from earliest times to the present day.

ICT opportunity

Use secondary information sources from the Internet.

18.8 Describe, with essential chemical reactions, the extraction of pig iron from iron ore in the blast furnace and its subsequent conversion into steel in the basic oxygen furnace.

List the chemical reactions that take place at different places in the blast furnace.

18.9 Describe the production of copper from its ores.

See Standard 18.5

Produce a flow chart showing the production of copper from its sulfide ore. Use equations to illustrate the process and describe common mechanisms employed to minimise atmospheric pollution.

18.10 Be aware that large-scale extraction and refining processes are often damaging to the environment and that this has to be balanced against the benefits of the processes; list some of the steps taken to minimise environmental degradation in the processes studied.

Make a list of the potential negative effects on the environment of a specific Qatari industry or plant and find out what the company is doing to minimise these effects.

18.11 Understand the importance of recycling products such as metals and plastics and of designing products to make recycling easier.

Set up recycling operations in school with assistance from Friends of the Environment.

19 Recognise periodicity in the properties of elements

19.1 Relate the periodic classification of Mendeleev to the electronic structure of the elements.

Study the original work of Mendeleev, noting how he was able to predict accurately the properties of then undiscovered elements such as germanium.

Show in a table the relationship between Group number and the number of outer shell electrons, and how the similarities in properties of transition metals can be related to the constancy in the number of outer electrons.

19.2 Account qualitatively for the periodic trends in atomic radius, ionic radius, melting point and electrical conductivity of the elements and show how these properties are periodic.

Plot graphs showing the variation with proton number of atomic radius, ionic radius, melting point and electrical conductivity.

Discuss how these parameters could possibly be related to proton number and electronic structure.

19.3 Describe trends in the reactions, if any, of the elements of the third period (sodium to argon) with water, oxygen and chlorine, and of the resulting oxides and chlorides with water.

Investigate the properties of the oxides, hydroxides and hydrides of the third period.

19.4 Describe trends in the physical and chemical properties of the elements, and their simple compounds, within groups I, II, VII and VIII, and account for these trends in terms of electronic structure.

Investigate the properties of the elements of these groups and their common compounds. Develop experimentally, where appropriate, displacement series for the elements.

19.5 Know the common uses of elements and compounds in groups I, II, VII and VIII, and relate these to their properties.

Make a display showing some of the common uses of elements of these groups and their compounds.

ICT opportunity

Use the Internet to discover the main uses of the compounds.

19.6 Predict the characteristic properties of an element in a particular group using knowledge of periodicity in the properties of elements.

Predict the properties of elements such as rubidium, barium selenium, astatine and xenon and compare the predictions with the actual properties.

19.7 Know that the elements of the first transition series (titanium to copper) have similar physical and chemical properties and relate this to their electronic structures.

Investigate the typical physical and chemical properties of the more common elements (e.g. iron, nickel, copper) and some of their compounds (e.g. their oxides and common salts).

20 Know the important properties of metals and how these can be modified by the formation of alloys

20.1 Know that metals can be arranged in order of reactivity according to their reaction with agents such as air, water and acids, and that this order is related to their position in the periodic table.

Selectively revisit work done on metal reactions and the reactivity series in earlier grades. Investigate additional characteristics (e.g. the thermal stability of carbonates and nitrates) Predict the properties of a less common metal (e.g. nickel) from its position in the series and carry out investigations to test the predictions.

Account for the anomalous unreactivity of aluminium, given its position in the reactivity series.

20.2 List a number of alloys, including the common forms of steel, and their uses, and compare their properties with those of the metals from which they are made.

Tabulate the properties and uses of some common alloys with the help of information from sites on the Internet. Note specifically the importance of alloys of aluminium.

ICT opportunity

Use the Internet as an information source.

20.3 Explain, in terms of particle theory, why alloys are often much harder and more rigid than the pure metal from which they are predominantly made.

Download and study applets showing how the presence of foreign atoms in a metal lattice can affect its physical properties.

ICT opportunity

Use applets to illustrate a concept.

21 Understand the characteristic properties of acids and bases

21.1 Understand the characteristic properties of acids and bases in aqueous solution.

Use a variety of acids and bases to:

- *show the effects of different acidic and alkaline solutions on indicators;*
- *show typical reactions of acids with metals, carbonates and bases;*
- *show and explain the anomalous reaction between sulfuric acid and calcium carbonate.*

21.2 Explain qualitatively the differences in behaviour between strong and weak acids and alkalis in terms of the extent of dissociation and relate this to the pH scale.

Test the pH of a number of common acids and bases using pH paper and a pH meter.

21.3 Explain the changes in pH during neutralisation and justify the choice of indicator.

Measure the pH changes during a neutralisation and determine the end-point graphically. Relate the choice of indicator to pH at the end-point.

ICT opportunity

Automatically follow the pH during a titration.

21.4 Make salts from acids and bases by a variety of methods.

Make salts using techniques such as acid +insoluble base, acid + carbonate, precipitation and neutralisation using an indicator.

21.5 Know the mechanism by which the pH of buffer solutions remains stable, give examples and state their composition.

Study the effect on pH of adding small quantities of acid to some solutions (e.g. ethanoic acid/ethanoate solution, ammonia/ammonium solution), using water as a comparison.

Note some buffer solutions in nature (e.g. blood).

21.6 Know how the basicity/acidity of oxides changes across groups of the periodic table and that some oxides show both acidic and basic properties.

Investigate the action of acids and alkalis on the oxides of the elements sodium to chlorine in the periodic table.

21.7 Understand and use the Brønsted–Lowry theory of acids and bases.

Perform Brønsted–Lowry neutralisations such as the reaction between hydrogen chloride and ammonia.

List the conjugate acid–base pairs in equilibrium in a number of common solutions.

22 Know about the chemistry of our environment

22.1 Understand how carbon and nitrogen are recycled in nature and recognise that many of our activities interfere with these processes.

See Standard 16.2

Draw diagrams of the carbon and nitrogen cycles.

22.2 Know that human activities often involve the release into the atmosphere of undesirable gases and that, in most cases, there are natural processes (sinks) that remove these. Recognise that the concept of *residence time* relates to the relative rates at which a substance is supplied to and removed from the atmosphere.

Investigate what is known about the main sinks and residence times for some significant pollutants (e.g. carbon dioxide).

ICT opportunity

Use the Internet to access up-to-date information.

22.3 Know that carbon particles, carbon monoxide, sulfur dioxide and oxides of nitrogen may be released as a result of the combustion of hydrocarbon-based fuels and know the damage that these emissions can inflict on the environment.

Perform simple investigations on the concentration of particulate matter in the atmosphere.

22.4 Know that ozone is a form of oxygen formed when oxygen is subject to electrostatic discharges or high-energy radiation, such as in the upper atmosphere.

Investigate and discuss the smell a photocopier, noting why photocopiers must be used only in a well-ventilated room.

22.5 Know that the pollutants from vehicle emissions can have consequences such as acid rain and the formation in the lower atmosphere, by photochemical free-radical reactions, of a number of hazardous compounds (such as peroxyacetyl nitrate and ozone).

Study the formation of secondary pollutants in photochemical smog and the importance of weather conditions in this process. Obtain measurements of key secondary pollutants (e.g. ozone) in Doha and study their variation with the seasons.

22.6 Know the main features of the structure of the atmosphere and describe the role of ozone in the stratosphere in reducing the intensity of harmful ultraviolet radiation reaching the Earth's surface; describe the process by which this layer is being damaged by free halogen atoms resulting from indiscriminate use of chlorofluorocarbons (CFCs).

Study the science behind the discovery of the 'ozone hole'; what the ozone layer is, how it is formed and why it is important; why the 'hole' occurs mainly in the southern hemisphere in spring, what causes it, what its implications are and what international agreements have been reached to address these.

ICT opportunity

Obtain data on the ozone layer and the Montreal protocol from the Internet.

22.7 Know why the build up of some gases, such as methane and carbon dioxide, in the atmosphere is leading to a warming of the atmosphere and climate changes.

Make a study of changes over time of the concentration of carbon dioxide in the atmosphere and of changes in the mean surface temperature of the Earth.

List and evaluate evidence for global warming (e.g. the break-up of ice flows, the loss of snow and ice from the summit of Mount Kilimanjaro, changes in average temperatures in Europe).

22.8 Outline developments and processes that have been introduced to reduce the main sources of atmospheric pollution.

Study International treaties such as the Montreal and Kyoto protocols. Consider processes developed to reduce air pollution (e.g. lean burn car engines and catalytic converters, flue desulfurisation, alternatives to CFCs) and make a display, possibly using ICT software.

ICT opportunity

Use ICT software.

22.9 Recognise the many functions of the oceans in regulating climate.

Compare the specific heat capacity and the specific latent heat of water with that of other liquids to demonstrate the effectiveness of the oceans as energy sinks and energy sources to the atmosphere.

Study the effects of major ocean circulations (e.g. the North Atlantic Gyre and the Benguela Current) on the climate of contingent continents.

22.10 Describe the water cycle and be aware of the importance of maintaining unpolluted groundwater, waterways and seas.

Debate the advantages and disadvantages of dumping waste at sea (including sewage as a source of nutrients and the problems associated with oil spillages).

22.11 Explain the preparation of potable water from impure water by the separation of solid material and purification by chlorine.

Make and test a model sewage works. Study the process of sewage purification in the main centres in Qatar.

Obtain information on what additives are put into water in Doha and why.

22.12 Explain the need for nitrogen- and phosphate-containing fertilisers and describe how their indiscriminate use can lead to pollution of ground- and riverwater.

22.13 Describe the process of eutrophication and its effect on water sources.

Investigate the eutrophication of an artificial pond in the school environment; include measurements of temperature, light and oxygen concentration.

ICT opportunity

Use a datalogger.

22.14 Understand the problems associated with the disposal of waste heat in large industrial complexes.

Study the mechanisms used to dispose of waste heat at one of the industrial complexes in Qatar.

23 Understand the fundamentals of reaction kinetics and equilibria

23.1 Know that reaction rates vary considerably and be able to produce, and analyse graphically, data from rate experiments.

23.2 Know and measure the effect on reaction rates of concentration, temperature and particle size, and explain the effect in terms of a kinetic particle model.

Show how the rate of the reaction between calcium carbonate and hydrochloric acid varies with concentration, heat and particle size.

Demonstrate the effect of a catalyst in reactions such as the combustion of hydrogen (platinum catalyst) and the decomposition of hydrogen peroxide (manganese dioxide catalyst).

Safety

Take appropriate care over the use of hydrogen and hydrogen peroxide solution.

23.3 Explain that in the presence of a catalyst a reaction will have a different mechanism with a lower activation energy, and that such a reaction will proceed faster.

Construct qualitative energy profiles for reactions used to study the effect of catalysts.

See Standard 24.2

23.4 Distinguish between surface action catalysis (heterogeneous) and intermediate compound catalysis (homogeneous) and give important examples of both.

Examples of surface action catalysts could centre on the use of transition metals and their compounds in industrial processes and in catalytic converters in vehicles. Intermediate compound catalysis could focus on enzyme action with examples from the biology standards.

23.5 Know that many reactions occur in multiple steps and that only one determines the reaction rate.

Discuss the very low probability of a three-way collision as a possible mechanism for a reaction such as $2H_2 + O_2 \rightarrow 2H_2O$ and suggest alternatives involving sequences of two-way collisions.

23.6 Explain a bimolecular reaction in terms of particle collisions and recognise that the chance of a reaction depends on particle concentration and particle energy.

Discuss and illustrate (the use of applets is desirable) the necessary prerequisites for a reaction in terms of particle theory, the necessity for a collision between reacting particles and for the collision to be energetic enough to cause a rearrangement of atoms.

ICT opportunity

Use Java applets to illustrate molecular collisions and reactions.

23.7 Understand, in terms of rates of the forward and reverse reactions, what is meant by a reversible reaction and dynamic equilibrium.

Show the reversible reaction between anhydrous copper sulfate or hydrated cobalt chloride (paper) and water.

Demonstrate the reduction of iron oxide by hydrogen gas and its reverse, the combustion of iron in the presence of steam. Consider as a 'thought experiment', what might happen if a mixture of iron filings are heated in an enclosed vessel to arrive at the concept of a dynamic equilibrium.

Safety

Both these reactions are hazardous and should not be done by students.

24 Understand reaction energetics

24.1 Know that chemical reactions are accompanied by energy changes, usually in the form of heat energy, and that the energy changes can be exothermic or endothermic.

Investigate exothermic and endothermic reactions. Suitable exothermic reactions are neutralisations and suitable endothermic reactions are those that involve the production of gases (e.g. the reaction between potassium carbonate or bicarbonate and hydrochloric acid).

24.2 Construct reaction energy profiles showing enthalpy changes in the reaction and activation energy.

Show similar examples where the heat produced by the reaction is sufficient to sustain it (e.g. the combustion of magnesium) and those where it is not (e.g. the oxidation of copper).

24.3 Know that a catalyst can provide an alternative energy profile with a lower activation energy.

See Standards 24.2, 24.4

Demonstrate and discuss the energy profile of a reaction such as the combustion of hydrogen with and without the presence of a platinum catalyst or the decomposition of hydrogen peroxide in the presence of manganese dioxide or dust as a catalyst.

Safety

Take appropriate care over the use of hydrogen and hydrogen peroxide solution.

24.4 Explain and use the concept of standard enthalpy change (ΔH), with particular reference to combustion, formation, solution and neutralisation, and calculate enthalpy changes from experimental results.

Measure experimentally some standard enthalpy changes (e.g. combustion and neutralisation).

Use the relationship $\Delta H = (mc_p\Delta T)/n$, where $(mc_p\Delta T)$ represents the heat produced from the reactions and absorbed by an appropriate medium, such as water, of specific heat capacity c_p.

Compare the heat energy released during the burning of different fuels; calculate the molar enthalpies of the reactions.

24.5 Recognise that bond breaking is associated with endothermic changes and bond formation is associated with exothermic changes.

Physics

By the end of Grade 10, students are familiar with fundamental and derived SI units, and use appropriate prefixes for small and large measurements. They handle inaccuracies and uncertainties when taking and manipulating measurements and distinguish between vector and scalar quantities. They understand, manipulate and represent graphically the concepts of displacement, speed, velocity and acceleration to solve problems related to moving objects. They know that a force can cause a change in velocity or shape of an object, resolve multiple forces acting on an object and distinguish between dynamic and static friction. They explain observations such as expansion, freezing, melting, boiling, evaporation, crystallisation, the Brownian motion and fluid pressure in terms of particle interactions. They have knowledge of the anomalous expansion of water and its importance. They understand density, flotation and pressure in solids and fluids, which they apply to hydraulics and pneumatics. They define and measure temperature and know why and how thermal energy moves from place to place. Students know that energy is transferred in the form of

pulses and waves, and understand and manipulate the measurable parameters associated with waves. They know that sound is a waveform that requires a medium, they measure its speed in air and know how the ear detects sounds. They know that light travels in straight lines and how it is reflected and refracted; they are aware of some of the applications of these properties. They understand dispersion and recognise some of its natural consequences, and know how the eye receives and focuses light. Students generate electrostatic charge in insulators, know the rules of electrostatic attraction, know how to use an electroscope to investigate charge and understand distribution of charge on a conductor They detect electric fields and know that they can exert a force on a conductor. They know that magnets have north and south poles and generate fields, the shape of which they plot, that exert forces on other magnets and on wires carrying a current. Students know that an electric current is a stream of charged particles and solve problems related to charge, current, potential difference and resistance.

Students should:

25 Measure and manipulate physical quantities and handle uncertainty in experimental results

25.1 Be familiar with fundamental and derived SI units and use appropriate prefixes, manipulate ranges of magnitude and express quantities correctly in standard form in SI format.

Tabulate objects of differing sizes from a proton to the Milky Way galaxy and indicate the size using the appropriate SI unit of measurement. Convert measurements from one unit to another, expressing the result in standard form.

Mathematics

Knowledge of standard form and SI format is required.

25.2 Distinguish between precision and accuracy; know how to ensure both in physical procedures.

Use a micrometer screw gauge to measure length and an electronic timer to measure time intervals precisely to a known margin of error. Repeat the measurements and take a mean to ensure accuracy.

25.3 Use and understand simplifying assumptions made in solving problems.

Draw attention, at the appropriate time, to sources of error that may be ignored in problem solving, such as air resistance in projectile motion, heat loss in thermal physics and cell internal resistance in electricity.

25.4 Distinguish between vector and scalar quantities, manipulate them appropriately and interpret their meaning.

Use examples in this and subsequent grades to show:

- *the addition and subtraction of vectors;*
- *the representation of vectors by lines;*
- *the resolution of vectors into perpendicular components and their addition by the method of components.*

26 Understand mechanics and kinematics

26.1 Understand the concepts of displacement, speed, velocity and acceleration, represent them graphically and interpret graphs that represent them.

Make calculations of velocity and acceleration using equipment such as an air track and interval timers or trolleys and ticker-timers.

26.2 Derive, from the definitions of velocity and acceleration, equations that represent uniformly accelerated motion in a straight line and use them to solve problems relating to the motion of objects under uniform acceleration.

Study qualitatively and quantitatively the motion of bodies falling in a uniform gravitational field in air or water. Measure the acceleration of a ball bearing due to gravity with an electronic timer and appropriate gates. Study the movement of an object moving under gravity using multiflash digital photography.

ICT opportunity

Use multiflash digital photography.

Use the equations of motion to solve problems relating the movement of objects under uniform acceleration in one and two dimensions (e.g. the movement of projectiles).

26.3 Know that a force acting on an object can cause deformation or velocity change.

Study the stretching of a spring up to and beyond its elastic limit.

26.4 Identify forces acting on a body, determine resultants, resolve forces into components and use the vector triangle to represent forces in equilibrium.

Study the forces (including their direction) acting an object suspended by two threads. Perform calculations on real objects in translation equilibrium with a number of forces acting on them.

26.5 Show a qualitative knowledge of frictional forces and viscous forces including air and water resistance and distinguish between static and dynamic friction.

Measure the static and dynamic frictional force required to move a variety of objects across a variety of surfaces.

26.6 Identify factors affecting friction and use the concepts of static and dynamic coefficients of friction.

Determine the coefficient of static friction for two surfaces in contact by measuring the friction angle.

27 Understand the nature of matter

27.1 Describe the kinetic particle model for solids, liquids and gases, and relate the difference in the structures and densities of solids, liquids and gases to the spacing, ordering and motion of particles.

Demonstrate, using models, the changes that occur as a solid is gradually heated. Dramatise the processes using the class as particles.

27.2 Use the kinetic particle model to explain fluid pressure, freezing, melting, boiling, evaporation, crystallisation and the Brownian motion.

Study the Brownian motion using a smoke cell.

Grow crystals of chromium potassium sulfate or copper sulfate. Cleave a quartz or fluorspar crystal.

Explain a variety of common observations in terms of the particle model.

27.3 Use the kinetic particle model to explain the thermal expansion of solids and liquids. List some of the problems this phenomenon can cause and how we solve them, and also list ways in which we make use of this phenomenon.

Study qualitatively the expansion of various solid rods.

Make and test a model thermostat from a bimetallic strip.

27.4 Use the concept of expansivity to solve numerical problems related to thermal expansion.

27.5 Explain how the anomalous expansion of water results in ice forming on the surface of water and not at the bottom, and understand the importance of this to the survival of living things.

Show how freezing water can break a sealed container.

Study the freezing of other liquids (e.g. ethanoic acid) to show that solids usually form at the bottom of the container first.

27.6 Know and use the concept of density.

Measure the density of a liquid, a gas and a regular and irregular shaped solid.

27.7 Understand and use the term *pressure* in the contexts of pressure exerted by a solid object and fluid pressure, and derive and use the relationship $p = \rho gh$.

Use a manometer to study how pressure increases with depth in water and how such fluid pressure is directionless.

27.8 Explain, in terms of the particle model, the hydraulic transmission of a force and know and explain quantitatively some common applications.

Make a model braking system or hydraulic jack using syringes of different sizes.

27.9 Understand why some objects float on water but others do not, and relate upthrust on a floating body to the weight of the fluid displaced.

Show that the weight of the water displaced by an irregular solid floating in water is equal to the loss in weight of the object.

28 Understand the properties of waves and know that sound is a waveform

28.1 Distinguish between a wave pulse and a continuous travelling wave, give examples of both and understand what is meant by *wavefront.*

Study simple examples of pulses and travelling waves. Study the movement of circular and plane wavefronts in a ripple tank.

28.2 Know that waves transfer energy and distinguish between transverse and longitudinal waves.

Show examples of longitudinal and transverse water and shock waves causing remote objects to move.

Show transverse and longitudinal pulses using a long spring or child's toy 'slinky'.

28.3 Know and use the terms *crest*, *trough*, *compression*, *rarefaction*, *displacement*, *amplitude*, *phase difference*, *period*, *frequency*, *wavelength* and *velocity*, and perform calculations using the relationships between velocity, frequency and wavelength.

Make measurements of the frequency and wavelength of water waves and calculate their velocity.

28.4 Know that sound is a longitudinal vibration transmitted through a medium, and that it is created by a vibrating object such as a vibrating string or air column.

Show how the pitch of a string or pipe depends on its length.

28.5 Know that the velocity of sound depends on the medium though which it travels, and that it travels faster and more efficiently through media in which the particles are close together.

Determine the velocity of sound in air using the echo method.

Compare qualitatively, the efficiency of transmission of sound through air and through a solid.

Use an oscilloscope to measure the velocity of sound in a metal rod.

28.6 Describe the way in which the ear detects sounds and know the approximate limits of human hearing.

Test the limits of hearing among class members using a signal generator and loudspeaker.

28.7 Distinguish between standing waves and progressive waves in terms of the production of sound by a musical instrument. Know how harmonics are produced and how the frequency and sound of the harmonics relate to the fundamental.

Show the relationship between the fundamental and harmonics using a violin or guitar string or the length of the closed pipe in a wind instrument.

Measure the frequency of a standing wave using a xenon stroboscope. Show harmonics using a wire or cord illuminated by a stroboscope set vibrating using a vibrator linked to a signal generator.

Safety

Stroboscopes are dangerous to sufferers from epilepsy

28.8 Distinguish between a standing and a travelling wave, know the meaning of the terms *node* and *antinode*, and illustrate the phenomenon of resonance with particular reference to vibrating stretched strings and air columns.

Show resonance of an air column using a column of varying length and a tuning fork.

Study nodes and antinodes in a vibrating string, using a strobe light, and in an air column using a Kundt tube.

29 Understand light and optics

29.1 Know that light travels in straight lines and can be reflected by plane surfaces, and explain how images are formed in plane mirrors. Explain common applications of this phenomenon.

Show reflection of light and the formation of images using common optical equipment.

Study the path of light through devices such as a periscope.

29.2 Know that light is refracted as it passes from one medium to another. Explain the geometry of refraction, calculate the refractive index of a medium and interpret it in terms of change in the velocity of light.

Show reflection of light using common optical equipment and calculate the, refractive index of several different media experimentally.

29.3 Show how images are formed by converging and diverging lenses and understand the concept of focal length. Explain common applications of these phenomena.

Study image formation by converging and diverging lenses, and determine the focal point and focal length of a converging lens.

Study the path of light through devices such as a magnifying glass, a camera, a telescope and a microscope.

Develop ray diagrams experimentally to locate images formed by converging and diverging lenses, leading to a definition of the terms 'principal axis', 'focal point', 'focal length' and 'linear magnification'.

29.4 Know and explain some common uses of curved mirrors.

Study the use of mirrors in applications such as car headlights and reflecting telescopes.

29.5 Explain total internal reflection and its application in fibre optics.

Study total internal reflection in a glass block.

Demonstrate the transmission of light through an optical fibre and discuss its applications in, for example, telecommunications, medicine and engineering.

Demonstrate and develop the concept of critical angle.

29.6 Show and explain the dispersion of light.

Show the formation of an optical spectrum (using light from the Sun and a water prism made from a mirror immersed at an angle in a bowl of water).

Show how dispersion can be a problem in optical instruments such as a camera or binoculars and explain how it is overcome by the use of achromatic compound lenses.

29.7 Explain, in terms of refraction and dispersion, natural phenomena such as rainbows, mirages, the colour of the sky, the colour of sunsets and the difference between real and apparent depth of water.

Carry out the 'appearing coin' experiment and demonstrate other common consequences of refraction.

Demonstrate the path of light that causes natural phenomena such as mirages and rainbows.

29.8 Know how the eye receives and focuses light and how short and long sight can be corrected.

Determine the near and far points of the unaided eye and of the same eye with spectacles.

30 Understand the basic principles of electrostatics, magnetism and electromagnetism

30.1 Distinguish between conductors, semiconductors and insulators with reference to moving electrons or ions; know how the properties of semiconductors can be influenced by the presence of small quantities of impurities.

Demonstrate the movement of coloured ions in an electric field.

Define conductivity and compare the conductivities of different conductors, semiconductors and insulators.

Discuss the changes in conductivity of semiconductors doped with certain impurities and show how these can be exploited through npn and pnp junctions.

30.2 Know that friction can generate two kinds of electric charge on an insulator and that opposite charges attract but like charges repel each other.

Recall activities from earlier grades showing the production and properties of charged rods. Determine the charge on an object.

Use an electroscope to investigate charge.

Show the principles of charging an electroscope by induction.

Use a Van de Graaff generator to show properties of a charge-carrying conductor (e.g. point discharge, Faraday cage).

30.3 Describe an electric field as an example of a field of force and know that electric field strength can be defined as force per unit positive charge and that an electric field can be represented by means of field lines.

View electrostatic field patterns between high-voltage terminals (generated safely using a piezo-electric gaslighter) in castor oil containing grains of semolina or small seeds.

Safety

High voltages. Students should not use a mains powered high-voltage generator.

30.4 Make magnets from magnetic materials by a variety of methods. Know that they have north and south poles and that unlike poles attract and like poles repel each other.

Recall activities from earlier grades showing the production and properties of magnets.

30.5 Describe a magnetic field as an example of a field of force and know that it can be represented by means of field lines.

Plot the magnetic fields of a variety of magnets using a plotting compass.

Plot the field due to two magnets with like poles adjacent to show the neutral point.

Plot the field around a magnet placed in a fixed position in the Earth's field and show the neutral points.

30.6 Explain the properties of ferromagnetic materials in terms of the magnetic moment of unpaired electrons.

30.7 Know the pattern of the magnetic flux due to a single current-carrying wire, a coil and a solenoid and know how an iron core can affect the field due to a solenoid.

Show the effect of varying parameters in a solenoid (e.g. core material, current, number of coils).

Recall the main uses of electromagnets and make models of simple electromagnetic devices (e.g. a bell and a relay).

30.8 Know that the magnetic field around a current-carrying conductor (both a straight wire and a solenoid) can interact with a fixed magnetic field in which it is placed, generating a force that can be detected, measured and exploited.

Show the movement of wire a suspended in a magnetic field when a current is passed through it

Use a Hall probe to investigate magnetic field strength and direction.

Measure the force on a wire in a magnetic field using a sensitive top-pan balance.

Make and test a simple DC motor and explain its operation.

30.9 Show how a consideration of the force between two current-carrying wires leads to the definition of the ampere.

31 Understand the fundamentals of current electricity

31.1 Know that electric current is the rate of flow of charged particles, define charge and the coulomb, and solve problems using the relationship $Q = It$.

Demonstrate that current is the flow of charged particles using a Van de Graaff generator supplying charge through a sensitive galvanometer to two plates with a conducting ball suspended between them.

31.2 Define potential difference and the volt. Solve problems using the relationships $V = W/Q$, $P = VI$, $P = I^2R$.

Measure and compare the power consumption of a variety of electrical devices.

Measure the electrical power consumption of an electric motor raising a load and compare that with the mechanical power output.

31.3 Define resistance and solve problems using the relationships $V = IR$ and $R = \rho l/A$ for multiple resistances connected in series and in parallel.

Investigate the relationship between current and voltage for ohmic and non-ohmic conductors.

Investigate the dependence of resistance on heat and light in thermistors and light-dependent resistors.

Use different resistors as potential dividers.

31.4 Distinguish between electromotive force and potential difference and understand the concept of internal cell resistance.

Calculate internal cell resistance in a circuit by measuring the current in a circuit and the voltage across an external variable resistance as the resistance changes.

Explain why car headlights dim when the starter motor is used.