MARKHOR JUNIOR CONTEST

SCIENCE COURSE OUTLINE

PIONEER LEVEL

(Applicable to Pioneer VII & Pioneer VIII)

Chapter No.	Chapter Title	Topic No.	Topic Title	Concept Description
01	**Scientific Inquiry and Data Analysis**	01	**Evidence-Based Explanations**	Distinguishing observation, inference, hypothesis, theory and law, and how scientific explanations change with new evidence, as with atomic models and continental drift.
		02	**Designing Controlled Experiments**	Selecting variables, control groups, suitable ranges and intervals, and sample size, together with risk assessment and ethical considerations.
		03	**Measurement Uncertainty**	Instrument resolution, uncertainty as half the smallest division, significant figures and an introduction to percentage uncertainty.
		04	**Relationships Between Variables**	Directly and inversely proportional relationships, linear and non-linear graphs, and the meaning of gradient and intercept.
		05	**Correlation and Causation**	Interpreting scatter graphs, positive and negative correlation, confounding variables, and why correlation alone does not prove cause.
		06	**Evaluating Investigations**	Validity, repeatability and reproducibility, identifying limitations and sources of error, and the role of peer review.
		07	**Engineering Design and Optimisation**	Iterative design, testing prototypes against criteria, trade-offs between performance, cost and safety, and refining solutions.
02	**Cells, Tissues and Transport**	01	**Prokaryotic and Eukaryotic Cells**	Bacterial cells (no nucleus, circular DNA, plasmids) compared with plant and animal cells, and cell sizes in micrometres.
		02	**Cell Differentiation and Stem Cells**	Unspecialised stem cells differentiate into specialised cells such as sperm, ciliated and root hair cells. Medical potential of stem cells.
		03	**Plant and Animal Tissues**	Epithelial, muscle, nervous and connective tissues in animals, and meristem, epidermis, xylem and phloem tissues in plants.
		04	**Diffusion, Osmosis and Active Transport**	Concentration gradients, surface-area-to-volume ratio, turgid and plasmolysed plant cells, effects of osmosis on animal cells, and energy use in active transport.
		05	**Enzymes as Biological Catalysts**	The active site and lock-and-key model, enzyme specificity, denaturation, and effects of temperature, pH and substrate concentration on enzyme activity.

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03	Biological Molecules and Nutrition	01	Biological Molecules	Carbohydrates built from sugars (starch, glycogen, cellulose), proteins from amino acids, and lipids from fatty acids and glycerol.
		02	Energy in Food and Calorimetry	Measuring energy in food by burning it to heat water, calculating energy content, and interpreting nutritional labels.
		03	Physical and Chemical Digestion in Detail	Peristalsis, bile emulsifying fats, the role of the pancreas and enzyme sites along the gut, and absorption into blood capillaries and lacteals.
04	Photosynthesis and Respiration	01	Investigating the Rate of Photosynthesis	Measuring oxygen production by pondweed, the effect of light intensity, and interpreting limiting-factor graphs.
		02	Uses of Glucose and Mineral Ions in Plants	Glucose used for respiration, starch, cellulose, proteins and oils. Nitrate and magnesium ions and the symptoms of their deficiency.
		03	Cellular Respiration and ATP	Respiration in mitochondria transfers energy to ATP. Aerobic respiration releases far more energy per glucose than anaerobic respiration.
		04	Gas Exchange in Plants	Stomatal control, net gas exchange in light and dark, the compensation point, and using hydrogencarbonate indicator to show changes.
05	Transport Systems	01	The Cardiac Cycle and Heart Rate	Sequence of atrial and ventricular contraction, the role of valves, coronary arteries, natural pacemaker and artificial pacemakers.
		02	Blood, Tissue Fluid and Lymph	Substances carried in plasma, formation of tissue fluid, the lymphatic system, and an introduction to ABO blood groups.
		03	Cardiovascular Disease	Coronary heart disease, cholesterol and fatty deposits, risk factors, and treatments such as stents and lifestyle change.
		04	Mechanisms of Transport in Plants	Transpiration pull and root pressure in xylem, translocation of sucrose in phloem, and measuring water uptake with a potometer.
06	Gas Exchange and Excretion	01	Lung Function and Respiratory Health	Tidal volume and vital capacity, adaptations of alveoli for gas exchange, and respiratory conditions such as asthma.
		02	The Kidney and Osmoregulation	Filtration and selective reabsorption in the nephron, control of water balance by ADH, and treatment of kidney failure by dialysis or transplant.
		03	The Liver and Skin in Regulation	Deamination producing urea, detoxification by the liver, and thermoregulation through sweating, vasodilation and vasoconstriction.
07	Coordination and Control	01	Neurons and Synapses	Neuron structure and myelin, chemical transmission across synapses, and voluntary actions compared with reflex actions.

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		02	**The Eye and Its Responses**	Eye structure, accommodation by ciliary muscles and lens shape, the pupil reflex, and lens correction of vision defects.
		03	**The Endocrine System and Blood Glucose**	Pituitary, thyroid, adrenal glands and pancreas, insulin and glucagon in blood glucose control, and type 1 and type 2 diabetes.
		04	**Negative Feedback and Homeostasis**	How negative feedback loops maintain stable conditions, including temperature control by the hypothalamus.
		05	**Plant Hormones and Their Uses**	Auxins, gibberellins and ethene, and their uses as rooting powders, selective weedkillers and fruit-ripening agents.
08	**Reproduction and Development**	01	**The Human Reproductive System**	Structure and function of male and female reproductive organs, gamete production, and the hormones controlling the menstrual cycle.
		02	**Fertilisation and Foetal Development**	Fertilisation, implantation, the roles of the placenta, umbilical cord and amniotic fluid, and harmful effects of substances during pregnancy.
		03	**Sexual Reproduction in Flowering Plants**	Self- and cross-pollination, pollen tube growth and fertilisation, and seed structure (testa, cotyledons, plumule, radicle).
		04	**Asexual Reproduction and Cloning**	Natural asexual reproduction, cuttings and tissue culture, animal cloning, and the advantages and disadvantages of clones.
09	**Genetics and Evolution**	01	**DNA Structure and Function**	The double helix, complementary base pairing (A–T, C–G), genes as codes for proteins, and the contributions of Franklin, Watson and Crick.
		02	**Mitosis and Meiosis**	Mitosis produces identical diploid cells for growth and repair, while meiosis produces haploid gametes with genetic variation.
		03	**Monohybrid Inheritance**	Alleles, genotype and phenotype, homozygous and heterozygous, dominance, Punnett squares and predicted ratios.
		04	**Sex Determination and Inherited Disorders**	XX and XY chromosomes, inherited disorders such as cystic fibrosis, and interpreting family pedigree charts.
		05	**Mutation and Sources of Variation**	Mutations as changes in DNA, causes such as radiation and chemicals, and genetic and environmental sources of variation.
		06	**Evolution by Natural Selection**	Darwin's theory, evidence from fossils and antibiotic-resistant bacteria, an introduction to speciation, and causes of extinction.
		07	**Selective Breeding and Genetic Engineering**	Artificial selection in crops and livestock, genetically modified organisms such as insulin-producing bacteria, and related ethical issues.

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10	**Classification and Microbiology**	01	**Modern Classification Systems**	The three-domain system (Bacteria, Archaea, Eukarya) compared with the five kingdoms, evolutionary trees, and the use of DNA evidence.
		02	**Microbiology Techniques**	Aseptic technique, culturing bacteria on agar plates, and measuring zones of inhibition to compare antibiotics and antiseptics.
		03	**Microorganisms in Biotechnology**	Industrial fermentation, biogas production, mycoprotein, and microbial enzymes used in detergents and food production.
11	**Disease and Immunity**	01	**Communicable Diseases and Their Control**	Examples caused by viruses (measles), bacteria (tuberculosis, cholera), protists (malaria) and fungi, their vectors, and prevention strategies.
		02	**The Immune Response**	Antigens, antibodies and memory cells, primary and secondary immune responses, and interpreting antibody graphs after vaccination.
		03	**Development and Testing of Medicines**	Drug discovery, preclinical testing, clinical trials, placebos and double-blind trials.
12	**Kinematics**	01	**Scalars and Vectors**	Quantities with magnitude only compared with those with magnitude and direction, and finding resultant vectors in a line and by scale drawing.
		02	**Motion Graphs**	Gradients of distance–time and velocity–time graphs, and the area under a velocity–time graph as distance travelled.
		03	**Equations of Uniformly Accelerated Motion**	Using v = u + at and average velocity to solve problems involving constant acceleration, including free fall.
13	**Forces, Momentum and Equilibrium**	01	**Applying Newton's Laws**	Calculations using F = ma, inertia and mass, and identifying interaction force pairs in real situations.
		02	**Momentum and Its Conservation**	p = mv, and conservation of momentum in collisions, explosions and recoil.
		03	**Rate of Change of Momentum and Safety**	Force equals rate of change of momentum, and how crumple zones, airbags, seatbelts and helmets reduce injury.
		04	**Stopping Distance**	Thinking distance and braking distance, and how speed, reaction time, road surface and vehicle condition affect them.
		05	**Equilibrium and Moments**	Conditions for equilibrium (no resultant force or moment), calculations with beams and levers, centre of mass and toppling.
		06	**Hooke's Law and Elasticity**	F = kx, the spring constant, the limit of proportionality, and elastic compared with plastic deformation.
		07	**Circular Motion and Gravitation**	Centripetal force keeps objects in circular paths, and gravitational attraction between masses explains orbits.

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14	Energy, Work and Power	01	**Kinetic and Gravitational Potential Energy**	Calculations with KE = ½mv² and GPE = mgh, and energy transfers in falling objects and pendulums.
		02	**Work, Power and Efficiency Calculations**	Calculations with W = Fd, P = E/t and efficiency, applied to motors, lifts and appliances.
		03	**Machines and Efficiency**	Mechanical advantage and velocity ratio, analysing pulley systems, and why real machines are less than 100% efficient.
		04	**Electricity Generation and Energy Resources**	Stages in a power station (fuel, heat, steam, turbine, generator), introduction to nuclear fission, and comparison of energy resources.
15	Pressure and Fluids	01	**Pressure in Liquids**	p = ρgh, pressure at depth in dams and for divers, and measuring pressure with a manometer.
		02	**Gas Pressure and Boyle's Law**	Gas pressure explained by particle collisions, barometers, and pressure–volume relationships at constant temperature (pV = constant).
		03	**Hydraulics and Archimedes' Principle**	Pressure transmission in hydraulic lifts and brakes, upthrust equal to the weight of fluid displaced, and conditions for floating.
16	Thermal Physics	01	**Kinetic Theory of Gases**	Temperature as a measure of average particle kinetic energy, gas pressure from collisions, and the link between the Kelvin scale and absolute zero.
		02	**Specific Heat Capacity**	E = mcΔT calculations, an experiment to measure specific heat capacity, and the importance of water's high value.
		03	**Specific Latent Heat**	E = mL calculations for melting and boiling, interpreting heating and cooling curves, and cooling by evaporation.
		04	**Reducing Energy Loss from Buildings**	Cavity wall and loft insulation, double glazing, comparing methods by cost and payback time.
17	Waves	01	**Wave Behaviour**	Reflection, refraction and diffraction of waves, the effect of gap size on diffraction, and the wave equation v = fλ.
		02	**Sound and Hearing**	Measuring the speed of sound, structure of the ear, frequency range of hearing, infrasound, ultrasound and hearing damage.
		03	**The Electromagnetic Spectrum in Depth**	Shared properties of electromagnetic waves (speed 3×10^8 m/s in a vacuum), frequency–wavelength relationship, ionising radiation and applications.
18	Light and Optics	01	**Refraction and Refractive Index**	Refractive index as the ratio of the speed of light in a vacuum to that in a material, the critical angle and total internal reflection.

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		02	**Ray Diagrams for Lenses**	Images formed by a converging lens for objects at different distances, magnification, and uses in cameras, projectors and magnifiers.
		03	**Optical Instruments and Vision**	The eye as an optical system, correcting short and long sight, and the principles of telescopes and microscopes.
19	**Electricity and Circuits**	01	**Charge, Current and Time**	Q = It, the coulomb, and electron flow compared with conventional current.
		02	**Potential Difference and Energy**	Potential difference as energy transferred per unit charge (V = E/Q), and cells combined in series.
		03	**Resistance and I–V Characteristics**	I–V graphs for resistors, filament lamps and diodes, and thermistors and light-dependent resistors in sensing circuits.
		04	**Circuit Analysis**	Combined series and parallel resistances, current and voltage in mixed circuits, and an introduction to potential dividers.
		05	**Domestic Electricity and Power**	P = IV = I^2R, E = Pt, choosing fuse ratings, earthing and double insulation.
20	**Magnetism and Electromagnetism**	01	**Magnetic Effects of Currents**	Field patterns around wires and solenoids, the right-hand grip rule, and factors affecting field strength.
		02	**The Motor Effect and DC Motors**	Force on a current-carrying conductor, Fleming's left-hand rule, motor construction and factors affecting motor speed.
		03	**Electromagnetic Induction and Transformers**	Factors affecting induced voltage, AC generators, step-up and step-down transformers, and the national grid.
21	**Atomic Structure and the Periodic Table**	01	**Development of the Atomic Model**	How the models of Dalton, Thomson, Rutherford (gold foil experiment) and Bohr changed with new evidence.
		02	**Isotopes and Relative Atomic Mass**	Isotopes as atoms with different numbers of neutrons, and calculating relative atomic mass from isotopic abundances.
		03	**Electronic Configuration and Periodic Patterns**	Electron configurations of the first 20 elements and how they explain group and period patterns.
		04	**Groups 1, 7 and 0**	Reactivity trends in alkali metals and halogens, halogen displacement reactions, and uses of the unreactive noble gases.
		05	**Transition Metals**	High density and melting points, coloured compounds, ions with different charges, and use as catalysts.
22	**Chemical Bonding and Structure**	01	**Ionic Bonding**	Ion formation by electron transfer, dot-and-cross diagrams, ionic lattices, and properties such as high melting points and conduction when molten or dissolved.

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		02	**Covalent Bonding**	Shared electron pairs, single and double bonds, dot-and-cross diagrams for H_2, Cl_2, H_2O, CH_4 and CO_2, and properties of simple molecules.
		03	**Giant Covalent and Metallic Structures**	Structures of diamond, graphite and silicon dioxide, metallic bonding with delocalised electrons, and why alloys are harder than pure metals.
		04	**Linking Structure to Properties**	Predicting melting point, conductivity and solubility from bonding and structure, and an introduction to nanoparticles.
23	**Formulae, Equations and Quantitative Chemistry**	01	**Formulae from Ions**	Ion charges and polyatomic ions (SO_4^{2-}, NO_3^-, CO_3^{2-}, OH^-, NH_4^+) used to write formulae of ionic compounds.
		02	**Balanced Equations and State Symbols**	Writing and balancing symbol equations with state symbols, and an introduction to ionic equations.
		03	**Relative Formula Mass and the Mole**	Calculating relative formula mass and percentage composition, and an introduction to the mole as the amount of substance.
		04	**Concentration of Solutions**	Concentration in g/dm³ and an introduction to mol/dm³, preparing solutions and dilution.
24	**Energy and Rates in Chemical Reactions**	01	**Exothermic and Endothermic Reactions**	Energy released or absorbed in reactions, energy profile diagrams, activation energy, and measuring temperature change.
		02	**Rates of Reaction**	Collision theory, and how temperature, concentration, surface area and catalysts affect rate, measured by gas volume or mass loss.
		03	**Reversible Reactions**	Reactions that go both ways, such as hydrated copper(II) sulfate, and an introduction to dynamic equilibrium.
		04	**Electrolysis**	Movement of ions to electrodes, electrolysis of molten lead bromide and brine, and electroplating.
25	**Acids, Bases and Salts**	01	**Acids, Alkalis and Ions**	H^+ and OH^- ions, pH as a measure of acidity, and strong compared with weak acids.
		02	**Neutralisation and Titration**	The reaction $H^+ + OH^- \rightarrow H_2O$, titration with indicators, and finding exact neutralisation volumes.
		03	**Preparation of Salts**	Making soluble salts from acids with metals, bases or carbonates, making insoluble salts by precipitation, and naming salts.
26	**Metals and Materials**	01	**Metal Extraction and Redox**	Extraction by reduction with carbon or by electrolysis based on the reactivity series, and oxidation and reduction as gain or loss of oxygen and electrons.
		02	**Corrosion and Its Prevention**	Conditions for rusting, barrier methods, galvanising and sacrificial protection.

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		03	**Polymers, Ceramics and Composites**	Addition polymerisation (ethene to poly(ethene)), properties of polymers, ceramics and composites, and disposal problems of plastics.
27	**Chemistry of the Environment**	01	**Crude Oil, Fuels and Pollutants**	Fractional distillation of crude oil, alkanes as hydrocarbons, combustion products, and pollutants such as CO, SO_2, nitrogen oxides and particulates.
		02	**Water Treatment and Chemical Testing**	Producing drinking water and treating sewage, and identifying ions with flame tests and precipitation tests.
		03	**Evolution of Earth's Atmosphere**	How the early atmosphere changed over time, with oxygen increasing through photosynthesis and carbon dioxide stored in rocks and fossil fuels.
28	**Earth's Structure and Geological Processes**	01	**Seismic Waves and Earth's Interior**	Behaviour of P and S waves, shadow zones, and how they provide evidence for a liquid outer core.
		02	**Plate Tectonics: Evidence and Mechanisms**	Seafloor spreading, magnetic striping, matching fossils and rocks across continents, mantle convection and slab pull.
		03	**Plate Boundaries and Landforms**	Fold mountains, ocean trenches, rift valleys, volcanic arcs and transform faults, and managing geological hazards.
		04	**Geological Time and Rock Dating**	The principle of superposition, fossils as markers, relative dating, and the geological timescale.
		05	**Landforms of Erosion and Deposition**	River landforms (meanders, deltas), glacial landforms (U-shaped valleys) and coastal landforms.
29	**Atmosphere, Climate and Water Systems**	01	**Global Atmospheric Circulation**	Uneven solar heating, convection cells, global wind belts and an introduction to the Coriolis effect.
		02	**Weather Systems**	Air masses, warm and cold fronts, cyclones and anticyclones, and the monsoon system.
		03	**Natural Climate Variability**	Ice ages, El Niño, and interpreting long-term climate data from natural records.
		04	**Oceans and Freshwater Resources**	Ocean circulation and salinity, the distribution of fresh water, the role of glaciers, and causes of water scarcity.
30	**Astronomy and the Universe**	01	**Time, Seasons and Latitude**	Solar and sidereal days, solstices and equinoxes, and why polar regions have continuous daylight or darkness.
		02	**Tides, Eclipses and the Moon's Motion**	Spring and neap tides, the Moon's synchronous rotation, and why eclipses are relatively rare.
		03	**Planetary Data and Orbital Patterns**	Analysing planetary data, the relationship between orbital distance and period, major moons, and comet orbits.

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		04	**Stellar Properties and Life Cycles**	Nuclear fusion of hydrogen into helium, luminosity and temperature, an introduction to the Hertzsprung–Russell diagram, and how mass determines a star's fate.
		05	**Galaxies and the Expanding Universe**	Types of galaxies, the scale of the universe, redshift as evidence of expansion, the Big Bang and cosmic microwave background radiation.
		06	**Modern Astronomy and Space Technology**	Telescopes across the electromagnetic spectrum, space telescopes, satellite orbits, space missions and space debris.
31	**Ecology and Population Dynamics**	01	**Ecological Sampling**	Using quadrats and transects, and estimating population size by capture–recapture.
		02	**Population Growth and Limiting Factors**	Population growth curves, carrying capacity, and analysis of predator–prey population cycles.
		03	**Efficiency of Energy Transfer**	Calculating energy transfer efficiency between trophic levels, and losses through respiration, movement, heat and waste.
		04	**Biogeochemical Cycles**	The carbon cycle, the nitrogen cycle (fixation, nitrification, denitrification), the water cycle and the role of decomposers.
32	**Environmental Change and Sustainable Development**	01	**Monitoring Pollution**	Measuring air and water quality, lichens and invertebrates as indicator species, and noise levels in decibels.
		02	**The Enhanced Greenhouse Effect**	Sources of greenhouse gases, atmospheric CO_2 data, climate feedbacks such as ice–albedo, carbon footprints, mitigation and adaptation.
		03	**Biodiversity Loss and Conservation**	Habitat fragmentation and overexploitation, in-situ and ex-situ conservation, protected areas and international wildlife protection agreements.
		04	**Sustainable Resource Use**	Life-cycle assessment, sustainable agriculture, fishing quotas and the responsible use of non-renewable resources.
		05	**Waste Management Technologies**	Waste sorting, biodegradable plastics, electronic waste, and capturing landfill gas.
		06	**Sustainable Development Solutions**	Green technologies, renewable energy integration, and community-based conservation, such as the programmes that helped the markhor recover.

CURRICULUM SUMMARY

- **Total Chapters:** 32
- **Total Unique Topics:** 134
- **Biology and Life Science:** 41 topics (Chapters 02–11)
- **Physics:** 35 topics (Chapters 12–20)
- **Chemistry:** 26 topics (Chapters 21–27)
- **Earth and Space Science:** 15 topics (Chapters 28–30)
- **Environmental Science:** 10 topics (Chapters 31–32)
- **Scientific Investigation and STEM Thinking:** 7 topics (Chapter 01), with quantitative analysis applied throughout

PROGRESSION BEYOND ELEMENTARY

Elementary Level introduced organelles, Newton's laws, Ohm's law, atomic structure and simple equations. Pioneer Level develops each into deeper mechanisms and quantitative reasoning: enzymes, ATP, synapses, negative feedback, Punnett squares and meiosis in biology; momentum, kinematics equations, kinetic and potential energy, specific heat and electromagnetic induction in physics; bonding, the mole, concentration, reaction rates, electrolysis and titration in chemistry. Earth science adds seismic evidence and the expanding universe, and environmental science adds sampling, population dynamics and energy transfer efficiency. Investigation moves to measurement uncertainty, variable relationships and correlation versus causation.

PREPARATION FOR ASPIRANT

Pioneer gives students the core models, vocabulary and calculation skills of each science discipline: structure–property reasoning in chemistry, equations of motion and energy in physics, and genetics, homeostasis and cell transport in biology. With confident data handling and experimental evaluation, students are ready for the separate-subject depth and examination-standard rigour of Aspirant Level.