WEST AFRICAN SENIOR SCHOOL CERTIFICATE EXAMINATION
ENGINEERING SCIENCE

PREAMBLE

The examination is intended to test the candidate's knowledge and understanding of the basic physical sciences and their application to the solution of engineering problems.

OBJECTIVES

Candidates shall be expected to demonstrate:

(a) a broad knowledge of the scientific principles relevant to the engineering and construction industries,

(b) the ability to select and apply information, laws and principles to routine problems and to problems that are unfamiliar.

STRUCTURE OF THE EXAMINATION

There shall be two papers, both of which must be taken.

PAPER 1 (Objective) - This will consist of 60 multiple-choice/objective items to be answered within 1¼ hours. The paper carries 60 marks.

PAPER 2 (Essay) - This will be an essay-type test consisting of two sections, A and B to be answered in 1 hour 45 minutes. The paper carries 100 marks.

SECTION A: This will consist of 10 compulsory short-structured questions taken from any part of the syllabus. Candidates will be expected to answer all the questions within 45 minutes for 40 marks.

SECTION B: This will consist of **four** essay-type questions taken form any part of the syllabus.

Candidates will be expected to answer **three** questions in 1 hour for 60 marks. Each question carries 20 marks.

DETAILED SYLLABUSES

TOPIC	NOTES
1. FLUID MECHANICS	
1.1 FLUID PRESSURE	(a) definition of pressure. (b) variation of fluid pressure with depth and density of fluid. (c) Pascal's principle (the pressure exerted in fluid is transmitted in all directions). (d) applications e.g. car brakes, pumps, hydraulic press, siphon syringes, etc.
1.2 ARCHIMEDES PRINCIPLE AND BUOYANCY	(a) principles and laws of floatation. (b) application to corks, hydrometers, balloons, ships, boats, submarines, etc. (only calculations involving the upthrust of fully-immersed or floating objects will be required).
1.3 PRESSURE MEASUREMENT	(a) identification and principles of operation of different types of manometers and barometers e.g. mercury barometer. (b) atmospheric, gauge and absolute pressure and the relationship between them. (calculations of atmospheric pressure from the height of a mercury barometer is required).
1.4 FORCE ON IMMERSED PLANE SURFACES	(a) identification of the forces. (b) magnitude of resultant force of immersed plane surfaces. (c) qualitative treatment of centre of pressure. (d) applications and problems of dams, divers, submarines and sluice gates.
2. MECHANICS	
2.1 COMPOSITION AND RESOLUTION OF FORCES	(a) scalar and vector quantities. (b) graphical representation of forces as vectors. (c) principles of parallelogram and triangle of forces and their verification. (d) resolution of forces; both algebraic and graphical methods are required.

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2.2 EQUILIBRIUM OF COPLANAR FORCES	(a) explanation of coplanar and concurrent forces. (b) application of conditions of equilibrium for coplanar and concurrent forces in solving problems; both algebraic and graphical methods are required.
2.3 PRINCIPLES OF MOMENTS AND COUPLES	(a) explanation of principles of moments and couples. (b) determination of the magnitude and direction of moment of a force about a point. (c) application of principles of moments to the state of equilibrium. (d) application of principles of moments in everyday life e.g. the chemical balance, see-saw, crowbar, spanner, wheel barrow, etc. (problems involving non-concurrent forces and using algebraic methods only are required).
2.4 CENTRE OF GRAVITY, CENTRE OF MASS AND CENTROID	(a) distinction between centre of gravity, centre of mass and centroid. (b) determination of the centre of gravity, centre of mass and centroid of regular and irregular shapes; only algebraic methods are required.
2.5 POLYGON OF FORCES	(a) principles of the polygon of forces. (b) determination of forces in simple two-dimensional framed structures. (Knowledge of Bow's notation to determine the magnitude and nature of forces is required).
2.6 VELOCITY AND ACCELERATION	(a) concepts of velocity and acceleration, including acceleration due to free fall. (b) distinction between velocity and speed. (c) equations of motion. (solution of problems by both graphical and algebraic methods are required).

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2.7 NEWTON'S LAWS OF MOTION	(a) state and explain Newton's laws of motion. (b) distinction between mass, force and weight; units of these quantities. (c) solution of problems in relation with mass, force and weight. (d) verification of Newton's laws of motion by Fletcher's Trolley.
2.8 CONSERVATION OF ENERGY AND LINEAR MOMENTUM	(a) application of principle of conservation of energy and linear momentum to the solution of problems. (b) potential and kinetic energy. (c) verification of principle of conservation of linear momentum by Fletcher's Trolley.
2.9 WORK AND POWER	(a) distinction between work and power including work done by variable forces. (b) calculations involving work and power (Graphical methods will be limited to linear cases)
2.10 FRICTION	(a) laws of friction. (b) coefficient of friction. (c) distinction between static and dynamic friction. (d) practical application of friction and the value of coefficient of friction for different surfaces in contact; e.g. (i) brake lining materials on metal (0.7) (ii) well oiled, polished surfaces (0.5)
2.11 MACHINES	(a) definition and types e.g. single pulley systems, levers, inclined planes, belt drives, wheel and axle. (b) definition and relationship between mechanical advantage, velocity ratio and efficiency. (c) effect or resistance to motion; forces acting on a body moving on an inclined plane. (d) graphical method to determine the law of a machine. (e) simple problems on all types of machines are required.

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2.12 ANGULAR MOTION	(a) relationship between linear and angular velocity; angular velocity defined as the number of radians (angular displacement) per second. (b) uniform motion in a circle. (c) velocity and acceleration. (d) difference between a couple and torque. (e) work done by couple and torque. (f) power as torque multiplied by angular velocity. (problems on torque will be restricted to uniform torque situations).
3. **THERMODYNAMICS**	
3.1 MEASUREMENT OF TEMPERATURE AND SCALE	types of temperature scales: (i) celsius scale (^{o}C), (ii) kelvin scale (K), (iii) absolute temperature scale. The relation K = ^{o}C + 273 is required.
3.2 THERMAL EXPANSION AND COEFFICIENTS OF EXPANSION	(a) explanation of coefficients of linear, superficial and volume expansion. (b) relationship between temperature and change in linear dimensions for solids and volume for liquids and gases. (c) application of thermal expansion and contraction and means of minimizing unwanted effects of thermal expansion. (d) expansion of metals and liquids including bimetallic strips and its uses. (e) experiments with ball-and-ring/bar-and-gauge should be known. (f) problems involving changes of temperature and dimensions of substances are required.
3.3 HEAT CAPACITY	(a) definition of specific heat, latent heat, change of state, sensible heat, mixtures.

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	(b) distinction between (i) sensible heat and latent heat, (ii) specific heat capacity and specific latent heat. (c) experimental determination by the method of mixtures of (i) the specific heat capacity of a piece of metal, (ii) the latent heat of ice. (d) problems on mixtures are required.
3.4 GAS LAWS	(a) Boyle's law and Charles' law. (b) solution of problems involving Boyle's law Charles' law and the characteristic gas equation (i.e. $\frac{PV}{T} = mR$). (c) ideal gases.
3.5 HYDROLOGY/HUMIDITY	(a) evaporation and condensation and factors affecting them. (b) moisture in the atmosphere and relative humidity. (c) understanding of concepts of saturated vapour pressure, dew point and relative humidity. (d) application of concepts to the principle of wet and dry bulb thermometer, pressure cooker.
3.6 HEAT TRANSFER – CONDUCTION	(a) explanation of molecular activity during conduction of heat. (b) definition of thermal conductivity. (c) simple problems involving Fourier's law.
3.7 FIRST LAW OF THERMODYNAMICS	(a) use of first law of thermodynamics to solve simple problems involving closed systems. (b) concept of internal energy.
3.8 PROCESSES	(a) the P-V diagram for simple processes, isothermal and adiabatic processes, constant pressure and constant volume. (b) solution of simple problems on P-V diagram including work done.

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3.8	INTERNAL COMBUSTION ENGINE		qualitative treatment of 2 and 4-stroke internal combustion (I – C) engines (petrol and diesel engines only).
4.	**LIGHT**		
4.1	LAWS OF REFLECTION	(a)	incident ray, normal, angle of incidence and angle of reflection at plane surfaces.
		(b)	regular and irregular (surface) reflection.
		(c)	method of no parallax.
4.2	REFLECTION ON PLANE AND CURVED SURFACES	(a)	characteristics of real and virtual images.
		(b)	application of reflection of plane mirror in simple periscope and meters e.g. mirror galvanometer.
		(c)	pin-hole camera.
		(d)	distinction between diverging and converging mirrors.
		(e)	characteristics of images in spherical mirrors, i.e. real, virtual, magnified, diminished, erect and inverted.
		(f)	application of curved mirrors in searchlights, driving mirrors, car headlamps, the use of convex mirror instead of plane mirror for driving mirrors.
		(g)	location of images in curved mirrors using ray boxes and non-parallel method.
		(h)	mirror formula $\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$ and magnification as $\frac{v}{u}$ should be known (derivation of these formulae is not required).
4.3	LAWS OF REFRACTION AND REFRACTIVE INDEX	(a)	explanation of laws of refraction and their verification by tracing a ray through a Rectangular glass block.
		(b)	definition of refractive index; absolute refractive index.
		(c)	determination of the refractive index of (i) glass,

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	(ii) water by the method of real and apparent depth.
	(d) problems on laws of refraction and refractive index are required.
4.4 LENSES	(a) use of the lense formula in calculation. (b) application of lenses in the human eye and in simple optional instruments e.g. cameras, binoculars, microscope, telescopes, projectors.
5. ELECTRICITY	
5.1 ELECTRIC CHARGES	(a) concepts of electric charge. (b) positive and negative charges; unit of electric charge (Coulomb). (c) demonstration of charges by rubbing different objects and bringing together to show opposite charges e.g. glass rod or cellulose acetate on ebonite or polyethene rod on fur.
5.2 SOURCES OF ELECTRICITY	(a) (i) chemical (primary and secondary cells), (ii) oil/coal fire power stations (steam), (iii) diesel generators, (iv) gas turbines, (v) hydro, (vi) nuclear, (vii) solar, (viii) wind, (ix) tidal. (b) the principle of one source should be known.
5.3 ELECTRIC CURRENT AND RESISTANCE	(a) current as the flow of electrons. (b) units and symbols.

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5.4 ELECTROMOTIVE FORCE AND POTENTIAL DIFFERENCE	(a) concepts of e.m.f. and p.d. (b) effects of internal resistance of e.m.f. e.g. simple cells, car battery.
5.5 CURRENT ANALYSIS	
5.5.1 OHM'S LAW	(a) explanation of Ohm's law. (b) experimental verification of Ohm's law. (c) identification of electrical symbols in simple circuits e.g. e.m.f., resistance, current. (d) drawing of electrical circuits is required. (e) calculations based on Ohm's law.
5.5.2 RESISTORS IN SERIES AND PARALLEL	(a) equivalent of resistors in (i) series, (ii) parallel. (b) calculation involving circuits with resistors in series and parallel. (circuits should not exceed three parallel external resistors).
5.5.3 KIRCHHOFF'S LAWS	explanation of Kirchhoff's two laws and their use in solving electrical network problems.
5.5.4 ALTERNATING CURRENT	(a) definitions and solution of problems on frequency, peak value, average value, r.m.s value, instantaneous value. (b) sinusoidal nature of the wave form of the electrical mains supply. (c) difference between the single-phase and 3-phase a.c. supply.
5.5.5 SERIES R.L.C. CIRCUITS	solution of problems and calculation of impedance for RL series, RC series and RLC series circuits.
5.5.6 PHASOR DIAGRAMS	understand the use of phasor diagrams to represent the relationship between current and applied voltage in series RL, series RC and series RLC circuits.
5.6 PROPERTIES OF CONDUCTING	(a) distinction between conductors and insulators and example of each type.

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	(b) concept of resistivity. (c) resistivity and conductivity. (d) temperature coefficient. (e) solution of problems involving the concepts.
5.7 HEATING EFFECTS OF CURRENT	(a) calculation involving energy and power dissipated in resistors and electric heating of liquid. (b) practical application of fuses, electric stove, pressing iron, immersion heater. (c) definition of capacitor, capacitance. (d) charging and discharging of a capacitor and its relationship to energy stored in an electric field and energy dissipated in the resistor.
5.8 POWER FACTOR	(a) concept of power. (b) effect of low power factor. (c) practical application (no calculations required).
5.9 ELECTROMAGNETISM	
5.9.1 MAGNETIC EFFECT OF ELECTRIC CURRENT	(a) direction of magnetic field associated with current carrying conductor. (b) determination of magnetic field associated with current-carrying conductor using the right-hand grip rule, iron filings and compass. (c) sketching of shape of magnetic field associated with a (i) long straight conductor, (ii) loop or single-turn coil, (iii) multi-turn coil (solenoid), (iv) permanent magnet.
5.9.2 FORCE ON A CONDUCTOR CARRYING CURRENT IN MAGNETIC FIELD	(a) factors that influence the forces on a conductor carrying current in a magnetic field. (b) use of Flemming's LHR to determine the direction of force. (c) concept or magnetic flux density and its units.

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	(d) solution of simple problems using F = BIL. (e) application to basic operation of simple d.c. motor.
5.9.3 E.M.F. INDUCED IN A CONDUCTOR	(a) experiment to show that induced current flows in a coil moving towards or away from a magnet is required. (b) problems on magnitude of induced e.m.f. using E = Blv, where B is measured in Tesla, l is measured in metres, v is measured in m/s.
5.9.4 LAWS OF ELECTRO-MAGNETIC INDUCTION	(a) Faraday's law. (b) Neumann's law. (c) Lenz's law. (d) application to the simple generator and motor vehicle spark plug. (e) use of Flemming's right-hand rule to determine direction of motion of conductor, the direction of magnetic field and the direction of the induced e.m.f. (f) problems on magnitude and direction of induced e.m.f. using the laws of electromagnetic induction are required.
5.9.5 SELF-INDUCTANCE	(a) explanation of self-inductance. (b) precautions to be taken when breaking an inductive circuit. (c) solving of problems using the formulae: $E = L\left(\frac{I_2 - 1_1}{t}\right)$, $W = \frac{1}{2} LI^2$, $L = \frac{N\phi}{I}$
5.9.6 MUTUAL INDUCTANCE	(a) explanation of mutual inductance. (iii) demonstration of how two coils can be mutually couple by (iv) variation of current in one coil, (v) variation of distance between the coils.

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	(c) solution of simple problems using the formula $E = M \frac{dI}{dt}$
5.9.7 APPLICATION OF ELECTROMAGNETISM	(a) qualitative treatment only. (b) application in everyday life e.g. telephone receiver (ear piece), magnetic separators for removing iron from crushed copper ore, the electric bell, lifting magnet, moving-coil instruments.
5.9.8 TRANSFORMERS	(a) principles of operation; transformation ratio. (b) construction (both core and shell type). (c) use of laminations. (d) simple problems on single phase transformers.
5.9.9 MEASURING INSTRUMENTS	(a) essential features of moving coil and moving iron instruments – deflecting, controlling and damping devices. (b) principles of operation and application. (c) comparison of the two types of instruments.
5.9.10 SEMI-CONDUCTOR DIODES	applications for detection, clamping, clipping and rectification.
6. CHEMISTRY	
6.1 ELECTROLYSIS	(a) principle of electrolysis; e.g. electrolysis of (i) acidulated water using inert electrodes. (ii) copper II sulphate solution using copper electrodes, (b) Faraday's first law. (c) application of electrolysis to electroplating, copper refinery. (d) solution of simple problems based on Faraday's first law.

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6.2 COMBUSTION OF BASIC FUELS	(a) explanation of combustion and the process of combustion. (b) determination of air/fuel ratios for the combustion of various fuels. (c) properties of hydrocarbon fuels e.g. calorific value, volatility, flash-point, octane rating. (d) simple problems involving determination of air/fuel ratios.
6.3 EXTRACTION OF ALUMINIUM	(a) the reactivity series and extraction of metals. (b) principal mineral sources of aluminium e.g. bauxite, kaolin, cryolite, felspar, corundum. (the chemicals names of the above-listed sources of aluminium are required). (c) principles of the methods of extraction of aluminium, e.g. (i) by electrolysis of solution of purified bauxite, (ii) action of potassium on aluminium chloride. (d) extraction of aluminium as a reduction process: i.e. $A1^{3+} + 3e^{-} \rightarrow A1$ reaction at cathode.
6.4 METALS AND ALLOYS	(a) properties and uses of the following metals: lead, tin, aluminium, copper, magnesium, nickel, zinc. (b) distinction between metals and alloys: e.g. brass, bronze, duralumin, invar, solder and magnesium-based alloys. (c) main constituents of alloys. (properties should include: mechanical, thermal, electrical and resistance to chemical action).

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7. STRENGTH OF MATERIALS			
7.1	STRESS AND STRAIN	(a)	definition of the following terms: stress, strain, tensile strength, yield stress, working stress, factor of safety.
		(b)	verification of Hooke's law.
		(c)	load-extension graph for ductile materials and identification of critical points and regions.
		(d)	simple problems based on Hooke's law.
7.2	BENDING MOMENTS AND SHEARING FORCES	(a)	concepts of shearing force (S.F.) and bending moment (B.M.).
		(b)	application of the maximum values of shearing force and bending moment for the selection of sizes of beams.
		(c)	simple problems will be restricted to light beams supported at the ends and carrying point loads.
7.3	PROPERTIES OF MATERIALS	(a)	brittleness, ductility and plastic deformation as applied to engineering materials.
		(b)	distinction between brittle and ductile materials and examples of each.
		(c)	plastic deformation; explanation using load-extension graph.