

II-9 工学部 電気工学科 電子



## PROPOSED SYLLABUS FOR A 4-YEAR COURSE IN ELECTRONICS

### ENGINEERING TECHNICIAN

#### FIRST YEAR

##### WORKSHOP

Standard hand tools for the bench fitter: description, care and maintenance. Pliers (including electricians' and round-nosed). Screwdrivers, shears, scissors, side and front cutters, strippers, crimping tools. Spanners, description by type and size: their care and use. Simple marking out. Exercises using files, hacksaw, hammer and flat chisel, rule, square and calipers. Exercises in the manipulation of non-ferrous metals and insulating materials. Exercises using centre-punches, hand drills, taps and dies, screwdrivers and spanners. Correct use of portable power drills and drilling machines. Safety precautions. Methods of holding down work pieces. Use of coolants. Use of measuring equipment, such as dividers, wire gauges, surface and depth gauges (not in detail). Introduction to reaming. Fitting of pins and dowels. Simple sheet-metal work exercises introducing cutting, drilling, punching and bending. Typical methods of fastening, e.g. anchor nuts, rivets, special screws. Soft soldering. Introduction to tools and materials. Use, care and maintenance of soldering irons. Practice in tinning and the jointing of tinned parts. Examination for good and bad joints. Types of soldered connections. Soldering of wires, flexes and small components to tags and tag-boards and printed circuit boards. Examination of cables as used in the sheathed wiring system. Methods of preparing terminations including crimping. Exercises on the above. Introduction to wiring techniques associated with electronic apparatus.

##### CRAFT THEORY

Instruction in safety precautions when using tools. Codes of conduct in workshops. Variations in common tools and their applications. Introduction to engineering materials such as iron, steel, copper, brass and aluminium. Mechanical and electrical properties of materials used as conductors and insulators. Types and forms of screw thread. Screw and bolt heads. Correct sharpening of twist drills. Tapping sizes.

Introduction to precision measuring instruments, micrometers; dial, surface and depth gauges.  
Introduction to tolerance limits and fits. Limit gauges.  
Introduction to basic techniques of sheet metal work, e.g. marking or modifying sheet metal trunking arrangements and chassis.  
Solders, fluxes and their uses. Composition of common solders.  
Methods of soldering.  
Typical domestic distribution systems, including application of consumer control unit.  
Consideration of electricity distribution systems.  
Assessment of cable and fuse sizes for simple installations.

### ELECTRICAL PRINCIPLES

Structure of matter. Simple electron theory. An electric current considered as the flow of electrons. Electric quantity. The coulomb and the ampere.  
Demonstration of heating, magnetic and chemical effects of electric current. Illustration of applications.  
Conductors and insulators. Electric circuits. Concept of resistance. Potential difference (in volts) as the cause of current flow. Ohm's Law. Simple calculations. Use of ammeter and voltmeter.  
Series and parallel circuits. Practical applications in heating and lighting.  
Calculations on resistors in series and in parallel.  
The primary and secondary cells as sources of electrical energy. Internal resistance. Cells in series and in parallel.  
Resistivity and conductivity.  
Heater elements. Effect of temperature on resistance. Resistance of conductors and voltage drop in cables.  
Rating of lamps and elements and resistors. Relationship between volts, amperes and watts.  
Electrical safety precautions. Earthing arrangements. Risk of fire and shock. Artificial respiration. Need for regulations.  
Electro-magnetic devices, bells, buzzers, relays. Simple bell and indicator circuits.  
Overloads and short circuits. Causes, effects and protection by fuses. Principles of protection and control by thermal and magnetic devices.

### RELATED STUDIES

Arithmetic - general revision, including fractions, decimals and conversions; reciprocals, ratios and percentages.

Calculations - areas of regular plane figures. Volumes and weights of simple solids.  
Metric system of weights and measures.  
Measurement and setting-out of angles, bisection of angles, construction of triangles and parallelograms.  
Interpretation of simple engineering drawings. Introduction to orthographic projection.  
The dimensioning of engineering drawings and sketches. Sketching of simple machine parts, using pictorial views, oblique and isometric.  
Thermal expansion and contraction. Measurement of temperature.  
Centigrade and Fahrenheit scales - conversion.  
Sketching and dimensioning for sheet metal work.  
Dimensional sketches of simple objects, e.g. terminals, cable lugs, fixing arrangements.

## SECOND YEAR

### ELECTRICAL PRINCIPLES

Types of supply: d.c., single-phase a.c., and three-phase a.c.  
Potential differences between mains and earth.

Meaning of "polarity" in distribution circuits. Live and neutral.  
Correct connection of single-pole switches, fuses and neutral links.  
Use of double-pole switches.  
Dependence of resistance on dimensions and materials. Mention of effect of temperature.  
The magnetic field. Flux magnetizing force. Field due to a current through a straight wire, loop and solenoid. Magnetic materials, permanent magnets.  
Force on a current-carrying conductor in a magnetic field. Basic principles of a moving-coil instrument and direct-current electric motor.  
Fundamental laws and examples of electro-magnetic induction (static).  
The transformer principle.  
Simple electro-magnetic devices. The electric bell, relay-contactors.  
The use of moving-iron and moving-coil instruments.  
Principles of telephone and loudspeaker. Simple telephone circuits.  
The simple generator principle (dynamic); generation of alternating voltage; rectification by commutator.  
Simple conception of alternating current: waveforms, frequency.  
Root mean square, peak, mean and instantaneous values.  
Introduction to the basic a.c. circuit. Use of inductor and capacitor.

## RELATED STUDIES

Use of algebraic notations. Use of formulae. Change of subject.  
Simple equations. Direct and inverse proportion.  
Plotting and use of simple graphs.  
Basic mechanics. Force units (including the newton). Work and power.  
Relations between mechanical and electrical units. Triangle and parallelogram of forces; simple applications.  
Moment of a force; torque. Levers (with parallel forces); beam balance; weighing machines.  
Mechanical and electrical units and the relationships between them.  
Efficiency. Heat as a form of energy. Units of heat.  
Specific heat. Relationship between electrical and heat units.  
Practical applications of the heating effect of a current including the filament lamp. Demonstration of conduction of current through gases and fluorescence.  
Further work on sketching, and reading of workshop drawings; sketching and dimensioning of electrical and electronic components.  
Further work on orthographic projection. Parallelogram and triangle of forces. (Graphical treatment.)

Plotting of sine wave by means of a rotating line.  
Properties of the right-angled triangle. Pythagoras' theorem.  
Further work on wiring diagrams using B.S. symbols.

## ELECTRONIC COMPONENTS AND CIRCUITRY

### 1. RESISTORS

- (a) Types of resistor: carbon, wire-wound, metal oxide; variable resistors; values and tolerance.
- (b) Measurement of component resistance and insulation resistance using commercial equipment.
- (c) Applications of the resistor in circuits; current divider and voltage divider.

### 2. CAPACITORS

- (a) Constructional features of different types of capacitor e.g. paper, mica, polyester; electrolytic; variable capacitors, values and tolerances.
- (b) Applications of the different types of capacitor in a.c. and d.c. circuits.
- (c) Measurement of capacitance using commercial equipment; multimeter and a.c. bridge.

### 3. TRANSFORMERS AND CHOKES

- (a) Types of choke and transformer; power types, audio high-frequency. Properties of magnetic materials. Ferrites, Mu-metal, permalloy, stalloy, HCR steel, dust cores.
- (b) Types of core: Shell, pot core, ring, C-core.  
Construction: Volts per turn, turns ratio, use of tapings, auto-transformer.  
Use of transformer as impedance matching device.  
Phase relationships. R.F. transformer.

### 4. LOSSES

R.F. resistance; skin effect, proximity effect, dielectric heating effect. Resonance at high frequency. Selectivity. Q factor.

### 5. VALVES

- (a) Thermionic emission
- (b) Diode and triode: Characteristics, anode a.c. resistance, mutual conductance, amplification factor, applications.  
Circuit symbols and identification of electrodes.
- (c) Pentode: Characteristics, applications, comparison with the triode.

### 6. APPLICATIONS OF THE VALVE

- (a) The diode as a rectifier.
- (b) The triode as an amplifier; single stage and multistage a.f. amplifiers.
- (c) The triode as an oscillator.
- (d) Amplifier testing. The use of the signal generator and cathode ray oscilloscope for amplifier testing.

### 7. SEMICONDUCTORS

- (a) Types of material; concept of electrons and holes as current carriers; concept of a barrier.
- (b) p-n junction diode; zener diode.
- (c) p-n-p and n-p-n junction transistors; current gains and leakages.
- (d) Introduction to thyristor.
- (e) Circuit symbols.

8. THYRATRON AND IGNITRON
  - (a) Characteristics of each. Circuit symbols. Identification of electrodes.
  - (b) Simple applications: as power switch; as controlled rectifier.
  
9. TRANSISTOR APPLICATIONS
  - (a) Transistor as an amplifier; amplifier configurations.
  - (b) Transistor as a switch.
  - (c) Transistor testing principles. Transistor circuit testing.
  
10. RELAYS AND CONTACTORS
  - (a) Types of relay: P.O. type; polarised type; plug-in; uniselector; reed.
  - (b) Applications of the relay in electronics.
  - (c) Maintenance and care of relays.
  
11. HANDLING OF COMPONENTS
  - (a) Component layout and mounting methods; chassis, printed board, tag strips.
  - (b) Soldering and desoldering: use of the heat-shunt.
  - (c) Transistor and valve mountings; heat sinks; valve bases. Plugs and sockets: types.
  
12. CONSTRUCTION OF CIRCUITS
  - (a) Mechanical construction.
  - (b) Component layout: earthing; stray capacitance; magnetic and electrostatic screening; filter circuits.
  - (c) Encapsulation of components.
  - (d) Circuit diagrams; reading of theoretical circuits. Wiring diagrams, block diagrams, layout drawings.
  
13. TYPES OF SUPPLY
  - (a) Batteries, types in use; selection for various applications.
  - (b) Power packs; valve and transistor types; stabilisation; voltage doubler.
  - (c) Oscillators and signal generators; elementary treatment by block diagrams. Types and uses.



#### 14. TRANSDUCERS

- (a) Microphones, pickups and loudspeakers.
- (b) Principles and uses of the following sensing devices.
  - (i) Light detection: photocell (emissive type); photodiode and transistor, light dependent resistor; infra-red detectors.
  - (ii) Thermal detection: thermistor; bi-metal contacts; platinum bulb resistor.
  - (iii) Magnetic detectors: reed devices; inductive devices. Electro-static detectors; capacitive. Radiation detectors: nucleonic sensors; photo-multiplier tubes. Application of servo device as a circuit input element.

#### 15. INDUSTRIAL CONTROL CIRCUITS

- (a) Use of amplifiers in control circuits: a.c. amplifiers; d.c. amplifiers; feedback systems. Simple servo systems. Use of stepping motor.
- (b) Typical circuits for safety guards, counting, fire detection, alarm systems. Their care, maintenance and testing.

#### THIRD YEAR

Part I R.T. & E. Technicians' Course.

#### FOURTH YEAR

Part II R.T. & E. Technicians' Course.

### THIRD YEAR

- NOTE: 1. Throughout this course SI units must be used.  
2. It is recommended to colleges that the use of the slide rule in all calculations be encouraged.

#### LABORATORY WORK

This course places a strong emphasis on practical work. It will take the form of project work, formal laboratory work and other practical activities. In addition, colleges are required to keep records of practical work and candidates must keep practical log books.

### MATHEMATICS

#### AIDS TO CALCULATIONS

Need for use of significant figures and approximations. Error and appreciation of error. Use of powers of ten in dealing with unwieldy numbers, e.g.  $22,400 = 2.24 \times 10^4$ ,  $0.00427 = 4.27 \times 10^{-3}$ . Percentages and per unit values.

Use of common logarithmic table for multiplication and division. Use of tables of squares, square roots and reciprocals. Use of logarithmic tables for calculations involving positive and negative whole numbers and fractional powers. The necessity for rough checks. The change of base of a logarithm, the use of natural (Napierian) logarithms. Construction and simple theory of slide rule. Use of slide rule for calculations including squares and square roots. Use of calculating machines. Binary numbers, addition, subtraction and multiplication. Change to denary number and denary to binary.

#### GEOMETRY

Measurement of solids such as cylinders, cones, spheres rings, and hollow cylinders.

## TRIGONOMETRY

Circular measure, the radian, conversion from radians to degrees. Trigonometrical ratios, sine, cosine, tangent, cosecant, secant and cotangent. Simple relations:

$$\tan\theta = \frac{\sin\theta}{\cos\theta}, \sin^2\theta + \cos^2\theta = 1, \sec^2\theta = 1 + \tan^2\theta = \operatorname{cosec}^2\theta = 1 + \cot^2\theta$$

Trigonometrical ratios for angles of any magnitude, defined using a rotating phasor. Solution of triangles using sine and cosine rules, area of any triangle, problems of heights and distances.

## ALGEBRA

Indices and their laws, positive and negative whole number and fractional powers. Use of logarithmic tables for calculations involving positive and negative whole numbers and fractional powers. Transposition of simple algebraic formulae. Evaluation of formulae using practical values. Formation and algebraic solution of simple linear simultaneous equations involving two or three unknowns. Simple electrical circuit problems e.g. Kirchhoff's Laws. Formation of quadratic equations and their solutions by factors, completing the square and by the use of the formula (without proof). Practical problems leading to quadratic equations.

## GRAPHS

Plotting of graphs for equations of the form  $y = mx + c$ ,  $y = \frac{k}{x}$ ,  $y = ax^2 + x$  straight line graphs, meaning of the slope and intercept. Use of straight line graph for determination of the law of the form  $y = mx + c$ ,  $y = \frac{k}{x}$ ,

$y = ax^2 + b$  and  $y = ax^n$ . Solution by conversion to straight line form by the use of logarithmic paper or scale. Graphical solution of linear simultaneous equation involving two unknowns and of quadratic equations. Mid-Ordinate rule, the determination of the areas of irregular figures, average value and r.m.s. value of alternating current waveforms.

Vectors, graphical representation and addition, addition by Pythagoras theorem, by trigonometry and by resolution. Application of phasors to the solution of electrical circuit problems.

Graphs of sinusoidal waves of different amplitudes and phase angles.

Meanings of amplitude, angular velocity, phase angle, wave-length, frequency and period. The relations between these quantities where applicable.

The relation between sine and cosine waves. Graphical addition of sinusoidal waveforms of the same frequency but of different magnitude and phase.

Ratios, proportion and variations. Engineering applications.

## ENGINEERING PRINCIPLES

NOTE: SI units must be used throughout.

1. Revision of definitions and units of mass; force and weight scalar and vector representation of a force. Resolution of a single force into rectangular components, application to simple practical problems. Resultant of two forces acting at a point determined graphically and by taking rectangular components. Triangle of forces and extension to polygon of forces, resolution of forces graphically and by resolution into components. Description of the turning effect of a force, unit of torque, calculation of torque for simple practical problems.
2. Definitions and units of velocity and acceleration. Distance-time and velocity-time graphs. Resolution of velocities. Introduction to Newton's Laws of motion and relation between force, mass and acceleration. Friction; coefficient of friction, friction force as equal  $U_x$  to normal reaction. Simple practical traction problems involving lifts, hoists and vehicles.
3. Definitions and units of work and power. Work done by force applied along, or at an angle to, the line of motion. Work done in lifting and by torque; work done against friction. Power as the rate of doing work; simple examples. Simple treatment potential kinetic energy, laws and gain of energy. Power as the rate of change of energy. Efficiency defined as output over input work; percentage and per unit presentation. Definitions of velocity ratio and mechanical advantage; their calculation for simple machines, such as lever, screw-jack and gear train.
4. Elementary idea of direct and alternating current. Electrical current as a flow of charge. Difference between conductors, semi-conductors and insulators. The e.m.f. as driving force produced by a source potential difference between two points in a circuit. Resistance as ratio of potential difference between two points in a circuit; to current. Ohm's law. Units of current, charge, potential difference resistance and conductance. Heat energy produced by current flow through resistance. Resistors in series and parallel. Direct current circuit problems on the parallel circuit, the series parallel circuits.

Calculations on power and energy dissipated in simple series and parallel circuits. Examples of methods of transit of power and energy, including simple calculations relating to electrical and thermal systems. Simple problems on cost of energy.

5. Relationship between resistance and conductor dimensions and dependence on material. Resistivity. Effect of temperature on resistance (introduced graphically), temperature coefficient of resistance referred to resistance at 0°C.
6. Elementary description of primary and secondary cells; lead-acid and nickel-alkaline cells. E.M.F. of a cell, internal resistance, effect on terminal voltage. Main characteristics of typical primary and secondary batteries. Principles of charging methods of secondary batteries. Simple calculation. Basic maintenance.
7. Description of the magnetic field produced by a current in a straight conductor, two parallel conductor and coil. Factors affecting the magnetizing force, the flux-density resulting from a coil carrying a current. The units of flux and flux-density. Force on a current-carrying conductor in a field as B.I.l. Practical applications of this force such as the motor and moving coil devices. Calculations relating to the transfer of electrical power and energy to mechanical system.
8. Principles and simple descriptive treatment of moving coil and moving-iron instruments, including arrangements for deflecting, controlling and damping. D.C. ammeters and voltmeters; applications. The effect of instrument resistance on circuit conditions. Shunts and multipliers, multirange and multi-purpose instruments.
9. Induced e.m.f. in moving and stationary circuits. Faraday's Law of electro-magnetic induction; introduction to Lenz's Law. Eddy currents and the need for laminated core.
10. Kirchhoff's Laws and superposition principles applied series-parallel circuits.

11. The magnetic circuit, magnetomotive force, magnetizing force, flux, flux-density, permeability, reluctance. Comparison between the magnetic circuit and the electric circuit. Relative permeability and its dependence on magnetizing force and flux-density. Description of magnetization curve and hysteresis loop; idea that energy loss is associated with the loop (but no calculations). Magnetic calculations for series circuits using magnetization curve or ampere turn method of solution excluding leakage and fringing. Path of magnetic flux in relays; unpolarised and polarised.
12. Induced e.m.f.; magnitude determined from rate of changes of flux linkage. Description of effects of self and mutual inductance, direction of induced e.m.f. calculation of e.m.f. of self and mutual inductance from rate of change of flux linkage or rate of change of current. Unit of inductance. Inductance in series, adding and opposing. Statement of energy stored in an inductor as  $\frac{1}{2} LI^2$  joules. Practical applications such as ignition system, transformer, etc.
13. Storage of charge in a capacitor. Relationship between charge and applied voltage; definition of capacitance. Capacitors in series and parallel; and hence relationship between capacitance and dimensions. Capacitance of the parallel plate capacitor. Potential gradient and dielectric breakdown. Importance of working voltage of capacitors. Statement of energy stored in a charged capacitor as  $\frac{1}{2} CV^2$  joules. Examples of construction of fixed and variable capacitors.
14. Generation of an alternating e.m.f. by rotation of a coil in a uniform magnetic field. Definition of cycle, period and frequency. Reason for use of sine wave; peak, half wave average and r.m.s. values by graphical means. Interpretation of expression of the form  $V = V_{\max} (\sin 2\pi ft + 0)$ . Wave form plotting from rotating vector, addition and subtraction of sine waves, resultant wave, effect of phase shift. Use of phasors for addition and subtraction; comparison of resultant with that obtained by plotting waves.
15. Resistance, inductance and capacitance in a.c. circuit considered separately in series and in parallel combinations. Impedance as the ratio voltage/current. (Examination questions will not include the resonant condition). Power in a.c. circuits.

16. Measurement of resistance by ammeter - voltmeter method (including allowance for effect of introduction of instruments) and by substitution. Principle and application of the Wheatstone bridge. Principles of the simple d.c. potentiometer application to measurement of potential difference, current and resistance.
17. Elementary qualitative treatment of the theory of semiconductors; the p-n junction. Thermionic emission, the simple diode, space charge, saturation. Types of rectifier, their characteristics and principles of operation. Single phase half-wave, full-wave and bridge connections only. Smoothing circuits. Comparison of input and output waveforms. The regulation curve protection, safety precautions.
18. The transistor, input and output characteristics, current gain in common-base and common-emitter configurations. The transistor voltage amplifier with a pure-resistance load; gain and use of load lines.
19. The thermionic triode; static characteristics and parameters and their determination. The triode voltage amplifier with a pure resistance load; gain and use of load lines.
20. Rectifier and thermocouple instruments for the measurement of current and voltage at audio and radio frequencies.
21. Principles of operation of loudspeakers, microphones and telephone receivers.

#### DRAWING AND PROCESSES

Work should be done in accordance with (BS 3939) I.S.O. 4,500

1. Elements of perspective, orthographic and isometric projections.
2. Layout of drawings; production of dimension sketches from descriptions.

3. The reading of mechanical drawings and the fundamentals of first and third angle projection.
4. Understanding assembly and detailed drawings and sketches of typical items of equipment in telecommunications, radio, television, electrical and electronic equipment.
5. Production of simple electrical layout and sequence (Schematic) diagrams, applied to electrical telecommunications, radio, television and electronic equipment using symbols specified in B.S. 3939 (Section 1, 1.1, 1.3, 1.4, 1.5.1, 1.5.2; Section 2; Section 3, 3.5, 3.6, 3.7, 3.8, 3.9, 3.10; Section 4; Section 5; Section 6, 6.1.1, 6.1.6, 6.9.1; Section 7, 7.1, 7.2; Section 8, 8.1; Section 9, 9.1, 9.5; Section 10, 10.1; Section 11, 11.1, 11.2, 11.5; Section 15; Section 17; Section 20, 20.2.1, 20.2.7, 20.3, 20.4, 20.5.7.

#### PROCESSES

6. The meaning of stress and strain; tensile, compressive and shear stress. Relationship between stress and strain within the elastic limit. Typical load extension graphs for ductile and brittle materials; simple physical limitations. Simple statement of Young's modulus. Meaning of safety factor.
7. Materials, properties and selection of ferrous, non-ferrous and insulating materials used in the electronics industry (Including modern dielectrics).  
  
Note: Students should be made aware of the most important properties needed in the selection of these materials, including cost and availability.
8. Metal joining by soldering and brazing. Common brazing spelters and solders. Types of fluxes used in electrical work. Problems experienced in soldering light cables electrical and electronic devices i.e. overheating, damping sleeving, and dry joints. Flow soldering, dip soldering and use of solder pots. Crimping, wrapping and other light cable connection methods. Termination of wires and cables.
9. Accuracy and limitation of hand processes. The use and cutting characteristics of hand tools such as files, chisels, snips, hacksaws, in the construction of electronic equipment.



10. The application of conducting and insulating materials in the construction of cables used in electronics, cable forms. Typical wires and cables for internal and external use.
11. Common screw thread systems; use of taps and dies. Lacking devices used in industry, e.g. lock nuts, spring washers. Application and construction of tap strips and terminal blocks. Simple forms of coil winding such as chokes used in electronic devices.
12. Description of typical items of telecommunications and electronic equipment; plugs, jacks, lamps, relays, keys, resistors, inductors, capacitors, and transformers. Distribution frames and protective devices. Requirements and materials for reliable electrical contact. Printed wiring. Colour coding of components.
13. Chemical effect of current; electrolytic corrosion due to (a) leakage or stray current (b) use of dissimilar metals in contact. Methods of preventing electrolytic corrosion.
14. Descriptive treatment of expansion of liquids and solids. Applications e.g. thermometers, bimetal relays, simple thermostats expansion in civil engineering structures. Definition of coefficient of linear expansion. Simple treatment of transfer of heat by conduction, convection and radiation. Practical applications such as heat sinks and cooling of equipment, material and methods used. Power rating of components; its dependence on surface area and ambient temperature.

## RADIO AND ELECTRONICS

NOTE: The treatment of this subject should be primarily descriptive of the function of the devices and not the analysis being stressed. Examples of circuits should be taken from practice using current circuit and function diagrams. Transistor versions should be considered in all circuits, and valves where appropriate.

1. Block diagrams of radio transmitters, radio and television receivers, digital computer systems, cathode-ray oscilloscopes and signal generators. Typical arrangements. The function of each stage.
2. The essential requirements for the transmission of information, frequency, bandwidth.
3. The use of a carrier. Amplitude modulation; modulation depth. Waveforms of a carrier, amplitude-modulated by a sinusoid. Statement of frequencies comprising the modulated waves of a carrier amplitude-modulated by (a) a sinusoid (b) a complex waveform and (c) pulses.
4. Demodulation of an amplitude-modulated wave. Circuits in common use.
5. The principles of frequency changing. Mixer circuits. Selection of i.f. advantages of superheterodyne over T.R.F. receivers.
6. Characteristics and essential features of gas filled diodes and triodes, pentodes, and field effect devices, semi-conductors diodes and transistors.
7. The amplifier. Typical requirements and frequency response. L.F. circuits including coupling, decoupling and biasing. The special requirements of wide band amplifiers. Requirements of power amplifiers, including matching and various classes of operation. Typical circuits and function of various components.
8. Descriptive treatment of use of feedback. Effect on gain, frequency response, input and output impedance, distortion and noise performance.

9. Requirements of i.f., r.f., narrow and wide band amplifiers. Typical circuits.
10. The requirements of a sinusoidal oscillator, stability, output typical circuits emphasising the similarity of various types consisting essentially of an amplifier and feedback elements to achieve oscillation. A wide range of examples should be considered and in each case the functions of the components discussed.
11. The construction and operation of the cathode-ray tube. Electron beams under the influence of electric and magnetic fields. Simple focusing and deflection.
12. Time bases, requirements. The function of a simple circuit for achieving linear sweep in electrostatic and electromagnetic tubes.
13. The use of cathode-ray tubes for picture reproduction. Explanation of terms used in T.V. systems e.g. line frequency, picture frequency, interlacing.
14. Practical power supplies, including half wave, full wave and bridge. Filter circuits. The regulation curve. Safety precautions. Protection.
15. Logical fault diagnosis. Introduction to ideas of fault location by logical testing in a simple series chain exemplified by a radio receiver. Half split method and its advantages.

#### PRACTICAL WORK

Half the available time for this subject should be devoted to practical work in the optional subject of radio and electronics, which should include the following.:-

16. Selection, performance, use and care of modern service test equipment. Diagnosis and correction of typical faults in simple equipment. The use of the cathode-ray oscilloscope and sweep generator. Preparations of practical test reports.

17. This practical work must be supplemented by appropriate integrated experience in industry.

#### FOURTH YEAR

#### MATHEMATICS

##### ALGEBRA GEOMETRY

Simplification of harder algebraic functions. The manipulation of technical formulae, including exponential and logarithmic forms. Reduction to a straight line law of variation  $y = ae^{kx}$ . (Graphical determination of the constants from given data.)

Cartesian and polar co-ordinates. Conversion. Equation of a circle. Polar equations of a circle. Complex numbers introduced as the roots of a quadratic equation and representation in the form  $a + jb$ . Graphical representation and in the form  $V/O$ . Addition, subtraction, multiplication, division, powers and roots of complex numbers. Application of complex numbers in simple electrical circuits.

##### DIFFERENTIATION

The derivative  $dy/dx$  as the limiting value of  $\frac{y}{x}$ . Differentiation from first principles of  $y = ax^n$ , where  $n = 1, 2, 3$ , or  $-1$ .

Differentiation of  $ax^n$  by rule,  $dy/dx$  of  $y = \cos\theta, \sin\theta$ . The graphical determination of  $dy/dt$  when  $y = \sin\omega t, y = \cos\omega t$  ( $\omega t$  in radians).

Rate of change, velocity and accelerations. Simple electrical applications.

Maximum and minimum values by consideration of  $d^2y$ .

## TRIGONOMETRY

Graphs of more difficult functions e.g.  $y = A \sin n$ . The compound angle formulae  $\sin (A + B)$ ,  $\cos (A + B)$ ,  $\tan (A + B)$ ; the double angle formulae  $\sin 2A$ ,  $\cos 2A$ ,  $\tan 2A$ . The half angle formulae  $\sin A$ ,  $\cos A$ ,  $\tan A$ . Addition theorems. Simple trigonometrical identities associated with the compound angle formulae. Solution of simple trigonometrical equations, including  $a \sin \theta + b \cos \theta = C$ . Approximations to ratios of small angles. Mathematical addition of sinusoidal functions of type  $a \sin \theta + b \cos \theta = I \cdot \sin(\theta + \alpha)$ .

## INTEGRATION

Integration as reverse process of differentiation. Integration of function of the form  $ax + b$ ,  $ax^n$ ,  $1/x$ ,  $e^{kx}$ ,  $\sin \theta$ ,  $\sin^2 \theta$ , etc. Significance of constant of integration in practical problems. The definite integral; use for determination of areas under curves and r.m.s. and average values. Comparison with results obtained by mid-ordinate rule.

## ELECTRICAL PRINCIPLES

1. Capacitance. Growth and decay of voltage in resistance-capacitance circuits without derivation of formulae. Time constant. Electrostatic shielding.
2. Inductance. Growth and decay of current in resistance-inductance circuits. Without derivation of formulae. Time constant.
3. Magnetic materials. Magnetization curves. Permeability, remanance. Coeffcivity. Hysteresis. Eddy currents: effect of lamination or granulation. Multipath magnetic circuits. Reluctance. Effect of air gap. Leakage magnetic shielding.
4. The ideal transformer. Voltage ratio: current ratio on load: phasor diagram with resistive load, equivalent input resistance on load. Brief discussion of power losses in a practical transformer.

5. Impedance and admittance of circuit elements. Reactance/frequency curves for L and C. solution of series and parallel circuits containing C, L, and R by phasor diagram methods and by using operator  $j$ . Power, power factor, and loss angle.
6. The utility of logarithmic units for the expression of ratios of powers, currents and voltage. Definitions of the decibel and its application to power, current and voltage ratios. Addition of gains and losses using logarithmic units.
7. Resonance in series and parallel circuits. Q - factor at resonance as  $WL$ : relationship to 3 dB bandwidth. Dynamic impedance at resonance and impedance at 3 dB points.
8. Introduction to field effect transistor. Field effect transistor characteristics and definitions of parameters. Bipolar transistors - definitions of 'h' parameters, in common base and common emitter configurations and their determination from characteristics.
9. Bipolar and field effect transistors and triode voltage amplifiers - Bypassing and load line calculations. Small signal equivalent circuits. (Biasing should include discussion of need of stabilisation of bias in common emitter configuration).
10. Simple bridges at balance. Maxwell. Hay and Schering bridge only.
11. The simple a.c. generator. Simple treatment of the characteristics of separately-excited and shunt-connected d.c. generators and motors.
12. Electronic voltmeters. Measurement of power at frequencies up to 30 MHz. Calibration of instruments for measurement of current and voltage. Influence of waveforms on meter accuracy. Form factor.
13. The use of cathode-ray oscilloscope for current and voltage measurements and waveform display. Explanation of limitations of use of C.R.O.

## RADIO AND ELECTRONICS

NOTE: The treatment of the subject should be primarily descriptive, the function of the devices and not the analysis being stressed. Examples of circuits should be taken from practice using current circuit and function diagrams. Transistor versions should be considered in all circuits, and valves where appropriate.

1. Further work on practical low-frequency, radio-frequency and wide-band amplifiers in common use, common-anode, common-collector, common-base, common-grid, common drain and common gate circuits. Feedback applications.
2. Attenuators, II T. ladder and  $m$ -derived filters.
3. Electron multipliers and photoelectric devices.
4. Further consideration of sinusoidal oscillators including phase shift.
5. Amplitude, frequency and pulse modulation. Frequency spectrum of the transmitted wave, single sideband operation, suppressed carrier and balanced modulator.
6. Demodulation. A.M. diode demodulators. Diode loads and their effect on video response. Filtering of i.f. and a.f. components. F.M. demodulators and limiters in common use.
7. Signal generators; specification indicating differences, types and uses.
8. Voltage doublers and multipliers, regulation. Voltage and current stabilisation using vacuum and gas-filled tubes. Zener diodes, transistors, non-linear devices and constant voltage transformers. Mains-borne interference.
9. Concept of constant current, constant voltage sources. Superposition and Thevenin's Theorems used for resolving d.c. resistive networks to the simplest equivalent forms.

10. Pulse generation and shaping circuits. Integrating and differentiating circuits.
11. Further time base circuits, including multivibrator and blocking oscillator. Requirements of electromagnetic and electrostatic deflection systems. The line output stage, automatic scan amplitude correction, 3rd harmonic tuning. S - correction. The field output stage. Methods of obtaining linearity. Synchronisation circuits. Controls associated with time bases and their functions.
12. Consideration of integrated circuits and microminiature techniques.
13. EITHER

Further treatment of f.m. and t.v. receivers. Second-channel interference and choice of oscillator frequency. Oscillator frequency stability. I.F. response shaping and acceptor and rejector circuits. Band pass and stagger tuning. Single sideband tuning v.h.f. and U.H.F. tuners, integrated tuner units.

OR

Operational amplifiers; differential amplifiers, virtual earth amplifiers, d.c. amplifiers and choppers. Stability and drift. Use of operational amplifiers in analog control and computation. Include reference to integrated circuit versions.



## TESTING METHODS

NOTE: This subject stresses the philosophy of fault-finding and testing methods and is the collection of work covered in previous years.

1. The need for testing-specifications, their purpose, types of test covered. Standards, specifications, their aims and uses. Tests to verify consistency of performance and continued satisfactory functioning. Testing of prototypes, small and large batch items. The relationship between testing, inspection, quality and reliability.
2. Testing techniques. Recording, tabulation, interpretation and analysis of results. Estimate of experimental error.
3. Instruments. Review of the application and limitations of electrical indicating instruments: moving-coil, moving-iron, rectifier, and thermal; electro-dynamic, electronic voltmeter, digital display, multi-range and multi-purpose indicating instruments. Distinction between instrument types, e.g., industrial and precision, portable and switch board. Sources of error; shunts and multipliers, the effect of frequency waveform. Review of simple practices to be observed before taking reading e.g., zero-setting, instrument position, scale factors, voltmeter and wattmeter against precision grade instruments (note BS89 recommendations). The preparation of correction graphs and calibration records.
4. Testing of a.c. and d.c. motors used for instruments and control.
5.
  - a. the need for maintenance principles.
  - b. Reliability and the connection between reliability and maintenance, meaning of mean time between failures. Reliability of systems. Quality control, acceptable variations.
  - c. Component reliability, common faults and effect of environment.
  - d. Factors affecting maintenance, operational requirements equipment characteristic, job environment.
  - e. Preventive maintenance: routine checks and replacement of unreliable items.
  - f. Corrective maintenance: Detection, location and rectification of faults. Methods of fault location: sequential and non-sequential. Random checks, half-split, beginning-to end techniques.
  - g. The problem of switches and interconnections.

6. Aids to maintenance: Use of manuals, circuit diagrams, test equipment. Information retrieval. Bench layout.
7. Automatic test equipment.
8. Importance of recording and analysing results of test. Costing.
9. Production line testing techniques, standards, test gear.

#### INDUSTRIAL ELECTRONICS THEORY AND PRACTICE

NOTE: The treatment of the subject should be primarily descriptive the function of the devices and not the analysis being stressed. Examples of circuits should be taken from practice using current circuit and function diagrams. Transistor versions should be considered in all circuits and valves where appropriate.

1. Concepts of industrial sources and application of r.f. and ultrasonic energy in electronic heating, welding and machining.
2. Gas-filled and semi-conductor devices for power control.
3. Binary Arithmetic; Boolean Algebra, AND, OR, NOT functions. Simple Boolean identities, truth tables, SIMPLIFICATION OF BOOLEANS expressions by use of de Morgans' theorems, VEITCH and KARNAUGH MAPS. Semiconductor diode AND, OR logic elements using both positive and negative going logic. Diode and transistor NAND and NOR logic elements (reference to recent integrated circuits versions must be included). Counting techniques; application to binary, ring and batch counters.

## CONTROL SYSTEMS

4. Transducers; the elementary theory, uses and systems associated with strain gauge.  
Piezoelectric, photoelectric, inductive, potentiometric and capacitive transducers.
5. Thermo-couples and thermistors.
6. Servometers; introduction to the principles and characteristics of d.c. motors and 2- and 3-phase induction motors.
7. Tacho-generators.
8. Synchro devices.
9. Electromechanical devices used with control systems: a.c. and d.c. solenoids and clutches, relays, uniselectors, microswitches, contactors, bimetal thermostats.
10. Automatic inspection, sorting and counting systems.  
Automatic machine control including pneumatic and hydraulic systems.
11. Electronic safety devices.
12. Principles of linear servo control systems: definition of and need for three-term control.
13. Practical application of proportional integral and derivative actions in power control.
14. Phase-sensitive circuit techniques as applied to modulation, demodulation and amplification for servo systems.
15. Simple treatment of potentiometric recorders.
16. Elements of digital control. Outline of data storage and transmission systems.
17. Fluidics.





