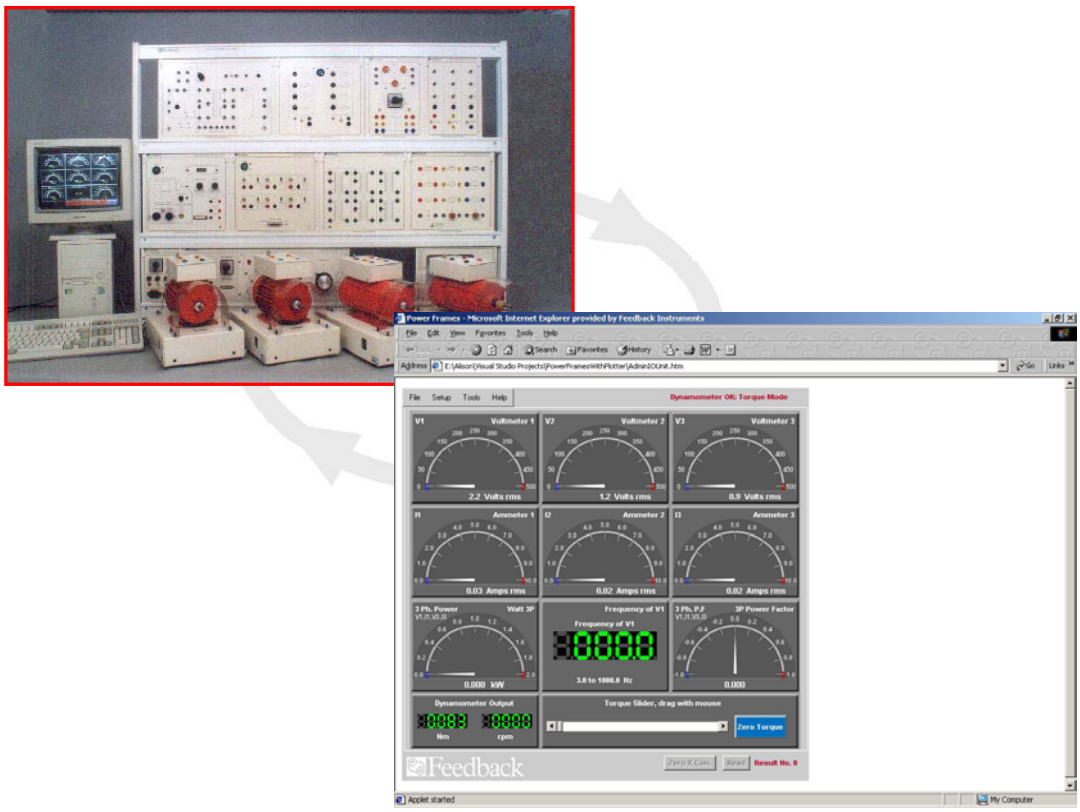
Electrical Power and Machines Laboratory

Planning Guide



Feedback Instruments Limited - World Leader in the design, manufacture and marketing of hardware and software for Engineering and Technology Training.

Table of Contents

Introduction

Education is the key that unlocks the door to future prosperity and stability in modern industrial societies. At Feedback we're proud to be part of that process – we provide institutions with the means to give hands on training for the very latest technologies.

It means that we're helping to nurture the skills and expertise that will one day provide the foundations of the fabric of our society and give us all a future to look forward to.

It's a responsibility we take very seriously, which is why we devote such energy and commitment to ensuring our customers receive the very best advice, products and support. It's what has made us one of the world's leading companies in supplying technological training solutions.

Feedback PLC

Feedback PLC is the corporate face of a group of high technology British Companies that address international markets in the provision of web-based training solutions through the design and manufacture of electrical, electronic and microprocessor based equipment for industry and education.

Founded in 1958, originally to meet a growing demand for 'hands-on' educational training equipment, Feedback is regarded as a premier supplier of reliable, high quality and competitively priced products.

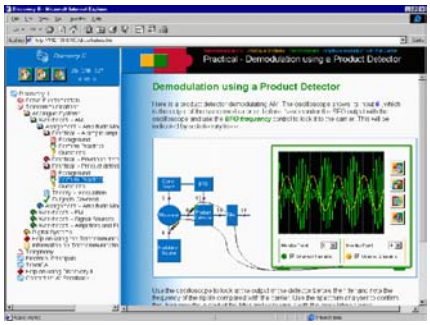
The Feedback group comprises the holding company Feedback PLC, Feedback Instruments Ltd, Feedback Incorporated, Feedback Data Ltd, Feedback Data GmbH and Feedback Hungary.

Companies within the group are ISO9002 approved and place much importance on quality in all areas of their operation. Equipment is rigorously tested to meet the latest standards and to ensure that it will continue to give reliable service for many years. To ensure quality Feedback operates its own Electro-magnetic Compatibility (EMC) test facility and complies with relevant European directives. All Feedback products are Year 2000 compliant.

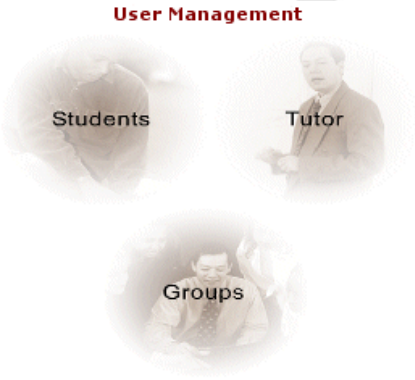
FEEDBACK INSTRUMENTS LTD.

Feedback Instruments Ltd. is a world leader in the design of Internet delivered teaching solutions using Computer Aided Learning and Computer Based Training equipment for technical training in education and industry.

Feedback Instruments employs highly qualified staff with backgrounds in both industry and education, maintaining close links with the world of education and training. Many product designs originate from universities and colleges world-wide. The product and software are developed to complement and support teaching requirements to meet the growing demands of new technologies.



Feedback Instruments acts as a consultant, providing advice on course structure, curriculum development and laboratory layout. Feedback Instruments also provides commissioning, training and after-sales service world-wide. Students and lecturers from all over the world visit Feedback for product training and to attend courses on specific areas of training and new technologies.



An integral part of the equipment is the software and courseware. The theory, background and practical instructional material allows the student to progress through a series of assignments using hardware and the unique ***Discovery software*** in either stand alone or through a web browser on an Intranet or Internet.
Discovery Manager is a browser based management system providing student administration, statistical monitoring, resource management and student records from an integral database. The system also provides the means to edit and create learning material and interactive question sets.

The product range includes equipment for:

- Analogue & Digital Electronics – covering the fundamentals building blocks of electronics.
- Control Engineering – covering hydraulics, pneumatics, analogue and digital servo systems, mechatronics, transducers and instrumentation, process control and advanced control techniques using the MATLAB© environment.
- Robotics – an integral part of any manufacturing system and a wide range of products are offered including simple anthropomorphic robots through CNC devices to sophisticated flexible manufacturing systems (FMS).
- Telecommunications – including advanced computer based training equipment covering analogue and digital communications, telephony, microwave, fibre-optics, antennas and transmission lines.
- Electrical Power and Machines – covering all areas from basic electrical principles to sophisticated power electronic control systems, using a flexible modular ‘frame’ system

RESOURCE BASED LEARNING

Resource based learning (RBL) provides a total solution for engineering and science teaching and training.

Using a centrally managed intranet system laboratory equipment is linked to the server via a managed learning environment to provide control, management and statistical records of student use and progress.

This type of flexible learning enables

- Students to access learning when convenient
- Reduced the need to equip laboratories with multiple numbers of identical equipment
- Enables students to access theory, background and underpinning knowledge at their desktops.
- Provides continuous assessment with multi-mode delivery with ICT results, and paper back up for student records

Laboratories are equipped with a variety of different equipments all linked to the management system. Students access the equipment via a unique login and the system records their activities via the links to the server. It is even possible to include existing older equipment that may not have a computer link by inputting the final results into the student database manually.

Students are tasked by the lecturing staff to complete assignments utilizing the laboratory equipment within a defined time period. All the instructions required to complete the assignment are on-screen and the results are locked into the student portfolio, with notification provided to the lecturer.

Different students can work on range of equipment moving around the laboratory to complete the assignments set.

Typical subjects offered are

- Analogue & Digital Electronics
- Data communications
- Computer assisted learning
- Mechatronics
- Telecommunications
- Robotics, CAD and FMS
- Instrumentation & control
- Process control
- Power & Machines

Discovery software

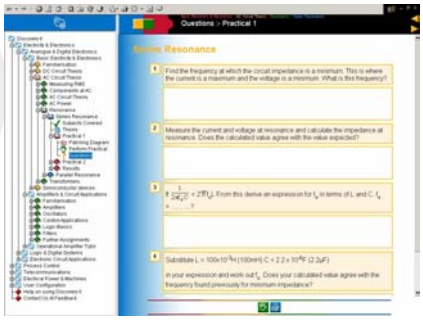
Discovery gives you total control of the learning environment, it enables you to;

- Integrate and present learning material
- Control and measure experimental hardware.

Discovery software uses the latest browser technologies and can be used in stand alone, network, intranet and internet environments.
The main features are,

- Navigation
  Discovery software incorporates a unique tool that enables the user to navigate around the system, whilst ensuring that their current position is always displayed.
- Theory
  Discovery software provides the theory and background information required to perform and understand the practical assignment work.
- Practical
  Discovery software has all of the test equipment required to perform the practical assignments on any connected hardware. Real time measurements are displayed on easy to use virtual instrumentation screens. Measurement points are mouse selectable.
- Question Sheet

Discovery software contains questions and answers that can be Printed by the student, or automatically forwarded to the tutor.



Discovery Manager

Discovery manager is a browser based Managed Environment for mixed technology laboratories that provides a unique on-line laboratory management. This new system is ideally suited for resource based learning in Technical training.
Features and Benefits…

- Latest browser based technology
- A served solution that can easily be upgraded and extended.
- Familiar interface and easy to use environment.
- An extensive range of wizards and tools to ease the creation of;
  Courses Classes Student details
  Content Reports.
- Extensive tracking of resources that significantly improves utilization and provides an audit trail.
- Extensive student accessibility enables flexible self-paced learning.

Discovery Manager consists of six key modules, these are:

- **User Manager.**
  Responsible for the creation, modification and deletion of data relating to students, lecturers and groups. A series of simple wizards guide the user through all operations.
- **Course Manager.**
  A tool responsible for the creation of group and individual learning programmes.
  A course can easily be created or modified using a series of wizards.
- **Learning Material Manager.**
  A large portfolio of learning material is available. This material consists of theoretical, background, practical experiments and associated questions and answers.
- **Report Manager.**
  A tool that collects data from within Discovery Manager. Data is collected from the following areas:
    - Course Reports
    - User Reports
    - Individual Reports
    - Group Reports
    - Resource Reports

The Data is stored in an SQL compliant database, additional statistics may be compiled

- **Resource Manager.**

This module is capable of controlling and tracking all training resources; these can be the resources within this proposal or any other part of the organization. These resources can be anything from rooms to multimeters.

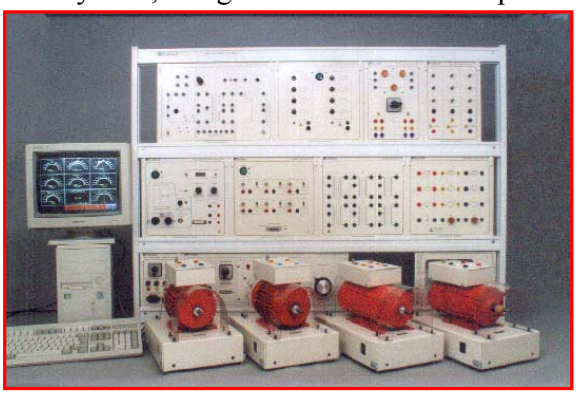
- **Configuration manager.**

Discovery Manager includes a configuration manager that allows global settings to be configured. Another of these sections is the definition of keywords, these are to allow standardization of terms throughout the system i.e. “pupil” or “student”, “term” or “semester” The module also allows the customization of fonts, colour schemes and navigational controls.

Introduction

The ***PowerLab*** System provides a flexible and cost-effective way to build a Power and Machines laboratory facility. It is a freestanding, bench top frame system, designed to accommodate panels from the Feedback range.

The Assignment work is covered with Laboratory Notes. These take the form of a CDROM with PDF documents which may be printed in whole or part as many times as you wish.



The Laboratory Notes contain objectives, equipment required, ancillary equipment, test circuits, practicals and results tables.

A Utilities Manual is also provided which details any assembly and set to work instructions.

The equipment specified in this proposal is for use in the engineering teaching laboratories of educational, industrial and military training establishments.

The equipment may be used at various levels of study and, in this general proposal, include equipment, which relate ***Electrical Power and Machines*** with other aspects of engineering.

It is assumed that the students entering any course, which utilises this equipment, will have an understanding of physics and mathematics together with a command of written and spoken English. It is further assumed that students will continue to study mathematics and both written and this equipment does not specifically cover oral communication techniques as part of any course, but these aspects.

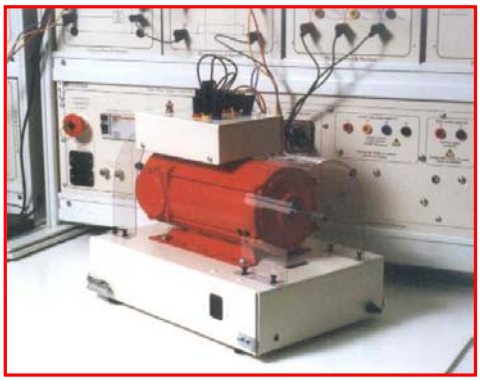
The virtual instrumentation screens have been designed to mimic the controls of a conventional instrument, thus the student will have a working knowledge of the real instruments.

The solution outlined in this document is scaleable for different numbers of students. There is no minimum or maximum quantity.

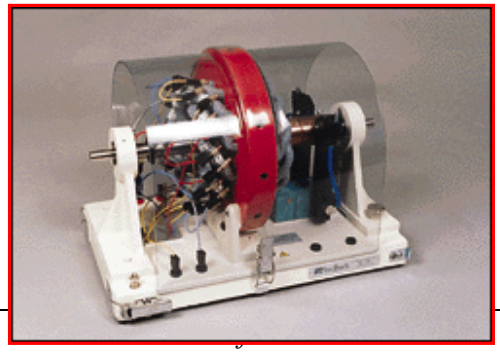
Choosing Electrical Machines Type

The two types of electrical machines available from our range lend themselves more suitably to different laboratory operating modes.

Industrial Type Machines: - Twelve different types of machines are available and this provides great flexibility for providing different motor and generator unit combinations at low cost. Students will move from workstation to workstation to complete a ring of assignments. This mode of operation we refer to as Serial Operation. The advantages of this method are lower cost and minimum preparation time before the experimental work can commence. When operating in this mode it is recommended that one Dissectible Machines Unit be acquired as a demonstration unit so that machines not covered in this laboratory can be demonstrated.



Dissectible Machine: - This provides over 50 different assemblies of dc, ac single phase and three phase machines. It is naturally more expensive than individual machines like those in our Industrial Machines range. It would be preferred when it is desirable for all students to carry out assignments on the same machine type at the same time. This operating

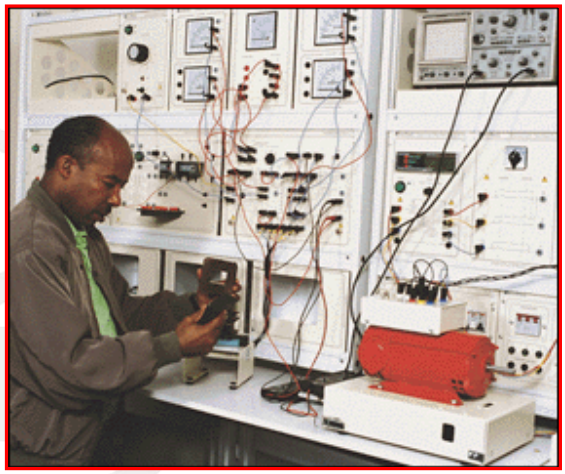


mode we refer to as Parallel Operation. They are particularly suitable where a large number of different types of machines are required to be studied at a detailed level.

Powerframes Electrical Systems and Machines Trainer

Powerframes is a series of **Electrical Systems and Machines trainers** based on the concept of complete systems that cover all your curriculum requirements in Electrical Power and Machines. The trainers provide the means to study the following areas:

- Electro-technology
- Single Three Phase Transformers
- Three Phase Systems
- Rotating Machines – dc, Single Three Phase
- Power Electronics



Each trainer is supplied complete with all necessary power supplies, loading and testing devices as well as an Interactive **Computer Control and Monitoring System**, which allows:

- Interactive Speed / Torque control
- Acquisition of test results
- Virtual Instrumentation

The system is complete with detailed laboratory notes that cover theory, experimental procedure and the practical operation of the units. These are provided on single sided sheets to facilitate photocopying.

System operating and installation instructions are also provided.

Safety is of prime concern.

The Power supplies include Emergency off button, Overload protection and optional earth leakage breaker. Double insulated colour coded shrouded plugs and leads provide safe and quick interconnections. All units have the means to be bonded to the supply earth. The frame is constructed of a fibre-composite material, which is electrically safe

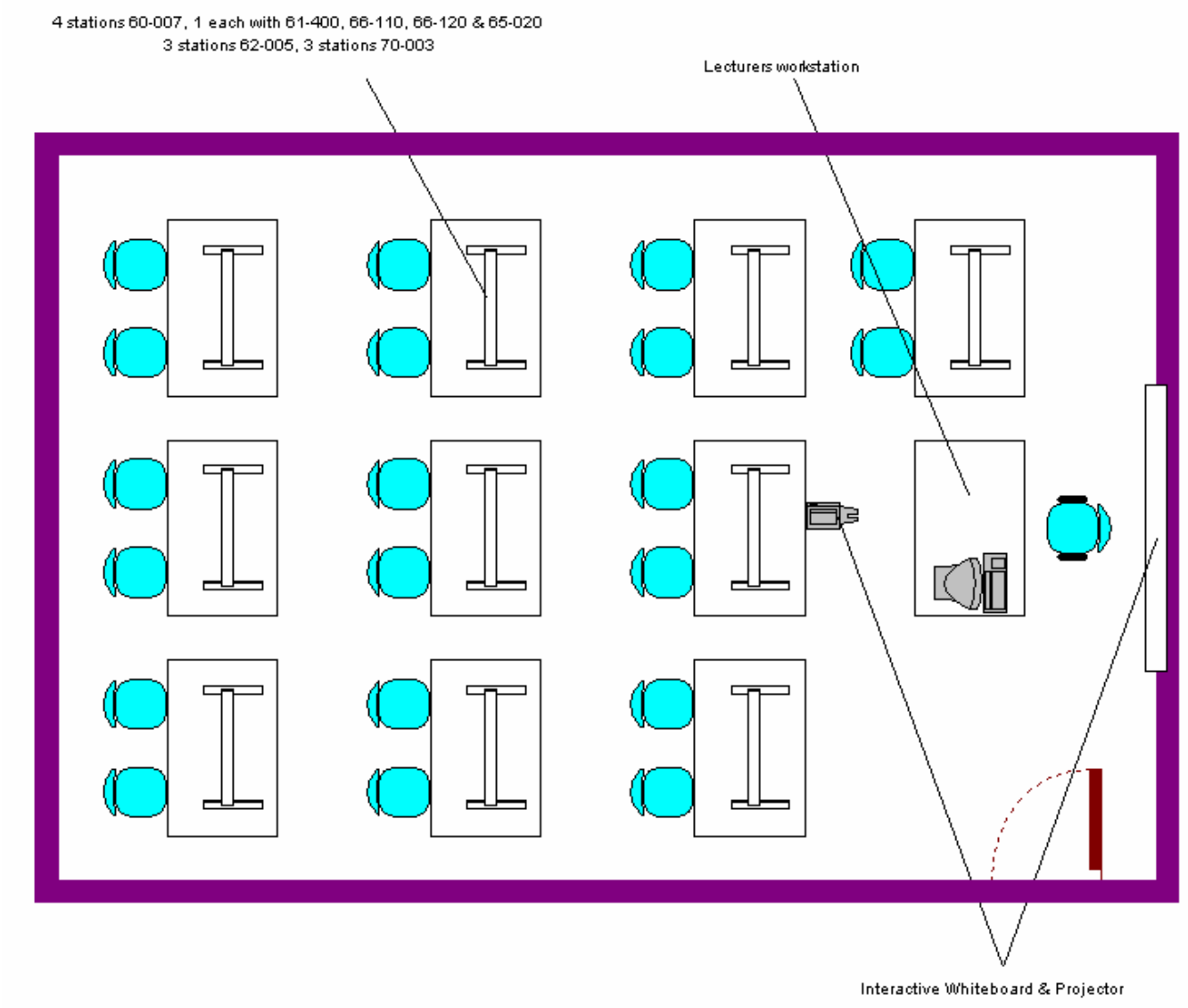
Curriculum Coverage

The following general curriculum areas are covered in this proposal.

- Introduces Magnetism and Electromagnetic Principles
- Introduces the Fundamentals of Electrical Technology
- Investigates the operational characteristics of Single and Three Phase transformers
- Investigates the Operational characteristics of DC Motors and Generators
- Investigates the operational characteristics of Single and Three Phase Motors and Generators
- Introduces Electromagnetic Motor control principles
- Introduces Three Phase Motor Control Techniques
- Introduces dc Motor Control Techniques
- Introduces and investigates Uncontrolled Rectification Circuits
- Introduces and investigates Controlled Rectification Circuits
- Introduces and investigates Power Electronic Firing Circuits, Thyristor phasing and Multi-pulse firing circuits in single and three phase
- Introduces and investigates Power Electronic Motor Control Circuits
- Introduces and investigates 4 Quadrant Drives
- Introduces and investigates

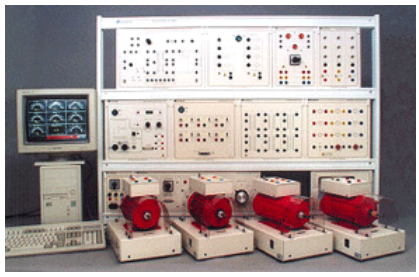
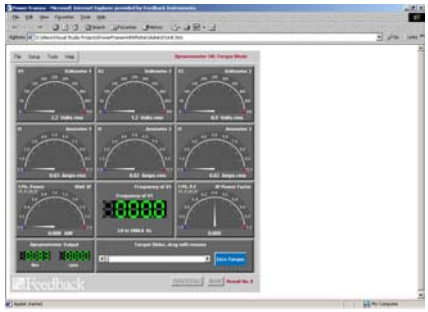
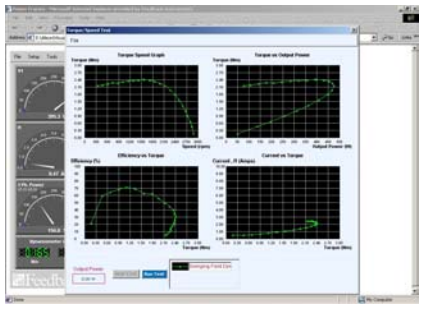
For more specific details on the curriculum coverage for each piece of equipment please refer to the product specifications.

Electrical Power Laboratory, Sample Layout.



Please note, the PC's, Interactive Whiteboard, Projector, Printer, Storage Cabinet and Furniture are not included in this proposal, if you require a quotation for these items please contact the sales office.

1	**3**	**Magnetics and Electromagnetics Trainer** [1] Magnetic and Electromagnetic Trainer is a complete teaching package that is specifically designed to provide the foundation teaching to the understanding of electrical power transformers and machines. [2] Consists of an ac/dc power supply unit incorporating loading resistors, filament lamp, metering and fixtures for the various magnetic and electromagnetic component assemblies. [3] The components consist of: • Permanent magnets • Iron, steel, and ferrite rods • Wound bobbins of differing turns • U and I cores, laminated and non-laminated • Induction/inductance rig • Magnetics platform rig • Plotting compasses • Single conductor rod [4] Covers the following curriculum; • Permanent magnetism and fields • Electromagnetism and fields • Forces between conductors • Magnetic field of a coil • Electromagnetic induction • Mutual inductance • Magnetic saturation • Transformer action • Transformer construction and materials • Transformer-winding polarity • Transformer-turns ratio [5] Weights and dimensions **Width** 580 **Height** 300 **Depth** 240 **Weight**….approx 20Kg.	

2	**4**	**Power and Machines Lab.** [1] Power and Machines lab is a complete teaching package covering the key areas of electrical power and machines teaching [2] The machines are purpose-designed industrial machines of small physical size but with characteristics more typical of larger machines. [3] The package is supplied with manuals on CD that provide a step-by step guide to setting-up and carrying-out the range of assignments associated with that package. [4] The system is based around a series of bench-standing machines of nominally 250W rating. [5] Power supplies, drive and control equipment, loading and instrumentation are all provided in the form of panels which mount into a purpose-designed, bench-standing frame and which can be easily slotted in and out as required. [6] Includes Single and Three-phase transformers along with all associated loading. [7] The frame is constructed of an advanced, fibre-loaded, rigid plastic material that is electrically insulating for safety. [8] The trainer contains the equipment necessary for the following curriculum; **Electrical Fundamentals** • Voltage, Current, resistance and Ohms law • Resistors in series and parallel • Power in DC circuits • Solving resistive networks using Kirchoffs laws **Alternating Current** • The sine wave, phase angle and power • Capacitive reactive, series & parallel equivalent capacitance • Phase shift and reactive current • Inductive reactance, series and parallel inductive reactance • Phase shift and reactive power • Power in ac circuits • Vectors and Phasors in RL, RC & RLC circuits • Impedance **Three phase Circuits** • Balanced 3-phase resistive load in star and delta connections • Root 3 relationships of Voltage and current measurements • Three Phase power measurements • Three Phase sequence determination. **Single Phase transformers** • Voltage & Current ratios, turns ratio, step-up, step-	  

		down • Voltage and current waveforms • Winding polarity, series and parallel connection • On-load characteristics, voltage regulation, inductive and capacitive loads • Auto Transformers, transformers in parallel, current Transformer **Three Phase Transformers** • Winding polarity, connecting star and Delta, open delta and zigzag secondary windings • Voltage and current relationships, establishing the root 3 factor • On-load characteristics • Voltage and current phasor relationships for no-load and on-load transformer • Phase shift between primary and secondary windings. **The Separately Excited dc Motor** • Principles of operation • Field current/shaft speed relationship • Armature voltage/shaft speed relationship • Armature current/output torque relationship • Effect of armature resistance on torque output **Series Shunt and Compound dc Motors** • Operating principles - Field current generation and shaft speed relationships • Torque/Speed characteristics of Series, Shunt and Compound motors • Comparison of characteristics • Armature current/torque relationships **Separately Excited, Shunt and Compound dc Generators, Cumulative and Differential** • Operating principles of a dc generator – residual magnetism, self excitation • Effect of field current variation on the generated output voltage • Generated voltage/shaft speed relationship • Critical resistance value in self excited generators • Output voltage/load current characteristics – Comparison of all types **The Universal Motor** • Field and Armature connections for ac and dc operation • Reversing the direction of shaft rotation • Torque/speed characteristics for ac and dc connections • Comparison of performance and understanding the need for compensation **ac Induction Motors** • Principles of operation of the Three Phase Induction	

		motor • Identification of windings • Reversal of shaft direction • Determination of shaft speed • Torque/speed, current, power, powerfactor and efficiency and efficiency relationships • Effect on motor speed and torque with supply voltage changes **Single Phase Induction Motors** • Principles of operation • Starting requirements – Main and auxiliary windings phase relationships • Types of starting circuits – RL, LC and L only • Shaft speed, supply frequency, machine pole relationship • Torque/speed characteristic, current, powerfactor and efficiency • Effect on motor speed and torque with supply voltage changes **Three Phase Synchronous Motor** • Operating principles – Starting requirements • Synchronisation to the Three Phase supply • No load running conditions – Effect of variation in rotor current upon line current and powerfactor • Behaviour as a synchronous capacitor • Torque/speed characteristic, current, power, powerfactor and efficiency relationships • Effect of rotor current variations on motor pull out torque • Operation as a synchronous capacitor or inductor (Vee curves) **Three Phase Synchronous Generator** • Operating principles compared to the Synchronous Motor • Open circuit voltage characteristic • Effect of rotor current variation on output voltage • Effect of shaft speed variation on frequency and output voltage • Load characteristic and voltage regulation of a non synchronised generator, with capacitive, inductive and resistive loads • Short circuit test and determination of synchronous impedance • Synchronising procedure of the Synchronous Generator • Power generation – Effect on drive motor torque and output power with variation in field current • Behaviour of powerfactor with variation in rotor current	

[9] The following equipment is provided with the trainer.

ac/dc Power Supply

- Circuit breaker protection
- Comprehensive Power Supply
- Three phase: nominally 0-400V ac line at 4A
- 3 x Single Phase: each nominally 0-230V ac line to neutral at 4A dc nominally 0-270V at 6A
- Three Phase 400V line, 230V Single Phase, fixed dc 220V 10A
- Single Phase power distribution
- Safety earth connection for all units

Universal Motor

- Rated at 250W continuous
- Maximum speed 6000 rev/min
- Power requirements 208V dc or Single Phase
- 230 ac 50Hz supply

dc Compound Machine

- Rated at 250W with separately wound shunt and series fields
- Nominal supply 180/220V dc armature and field
- Suitable for operation with separately excited connections
- Can be used as a dc generator
- Nominal speed 3000 rev/min

Capacitor Start Motor

- Rated 250W continuous
- Rotates at up to 2850 rev/min at 50Hz
- Power Requirements 220V Single Phase ac

Three Phase Synchronous Machine

- Can be used as a motor or generator
- Rated at 400/230V 300W
- Synchronous speed 3000 rev/min at 50Hz
- Power Requirement 380/415V Three Phase ac
- Rotor supply 100V dc max

Three Phase Induction Motor

- Rated at 250W
- Rotates at up to 2980 rev/min at 50Hz
- Power Requirement 380/415V star connected, 50Hz,

		Three Phase ac • Suitable for use with Star/Delta starters at reduced voltage **Switched Three Phase Resistance Load** • Three resistor switched load banks • Seven resistor values per bank • 547 – 3770 ohms per bank • 100W per bank • Total Three Phase loading for Star @ 400V or Delta @ 230V, 300 watts **Switched Three Phase Capacitive load** • Three capacitive switched load banks • Seven Values per bank • 1-7 uF per bank **Switched Three Phase Inductive Load** • Three inductive switched load banks • Seven Values per bank • 1.7 H-12H per bank **Single Phase Transformer** • Multi windings for series and parallel connection • **Three Phase Transformer** • Primaries for 380/415V ac star or delta connection • Two 115v 0.43A secondary per phase • Mimic of windings on front panel • 4mm safety sockets **Synchronizing Lamps** • Basic synchronising by Phase indicator lamps grouped in a triangle • Uses either lamps-bright or lamps-dark technique • A power switch is provided to connect the systems together. • Can accommodate Three Phase or Single Phase supplies. **Armature Current Dynamometer Machines Testing System** A complete automatic system for testing ac and dc electrical motors or generators, and Single Phase or Three Phase electrical systems. Comprising: • dc shunt machine fitted with dc tachogenerator	

		• Torque/speed control panel • Multi-channel I/O unit with I/O board & software **dc Shunt Machine fitted with Tachogenerator** The machine is mounted on a base unit with quick release catches and locating pins allowing easy coupling to other machines to be tested. A multiway connector is provided for field and armature to connect to the torque/speed control panel. The dc tachogenerator attaches to the motor base and motor shaft to provide a dc voltage or current output for connection to the electronic systems or speed controllers. • Rated at 250W with separately wound shunt field • Normal supply 180/220V dc armature and field • Is used as a dc generator when operated to measure torque and can be used as a variable speed drive for the testing of generators and alternators • Operating speed range: 0-5000 rev/min-1 for torque and 0-4000 rev/min-1 when used as a variable speed drive • Tacho output: 2V dc/1000 to 6000 rev/min-1 **Torque Speed Control Panel** • Connects to DC shunt machine to control the torque or speed of the machine under test. • LCD display of Torque or Speed • Constant torque or torque proportional with speed upto 4000RPM • Interlock system prevents inadvertent use. **Multi-channel I/O unit with PC card and software.** • Intended for electrical systems where several measurements need to be displayed on screen simultaneously • 6 isolated channels • 3 voltage and 3 current inputs • AC and DC measurements. ***Accessories*** **Patch Leads** For interconnections between panels and bench-mounted equipment, the leads are fitted with 4mm stackable shrouded safety connectors made from double insulated cable. All front panel power connections on the equipment are made with shrouded plug leads. **System Frame** • Easy 'lift-in/out' panel removal • Maximises bench space • Provides clear view of multi-panel experiments **Universal Bin**	

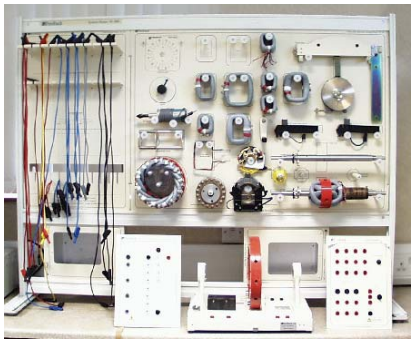
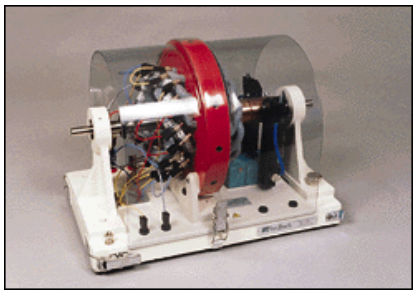
		• Holds items associated with the Powerframes System • Can be used in either landscape or portrait format **Shaft Coupling & Key** • Couples Feedback 64 and 63 series machines and motors for motor/generator and multi-machine experiments • 14mm shaft to 14mm shaft Weights and Dimensions (Assembled in frame) Width 1000 Height 800 Depth 500 Allow extra bench space for machines and storage area. Weight….approx 125Kg.	

3	**1**	**3 Phase PWM Motor Controller**
		
		[1] This unit should feature a panel mounted PWM controller that is compatible with the Electrical Power Engineering system specified above. It must be capable of controlling the three phase asynchronous motor provided within that system.
		[2] Assignments:
		• Investigation of PWM control
		• Effects of frequency on a squirrel cage induction motor
		• Soft starting an induction motor
		• Effects of motor acceleration and deceleration on the controller
		• Voltage Frequency Characteristics
		• Examination of controller settings:
		  • Voltage boost
		  • Max Speed
		  • Min Speed
		  • Acceleration/deceleration
		• Over Voltage protection
		• Controlling a 3 phase induction motor
			

4	**1**	**DC Motor Controller** [1] Suitable for use with DC Shunt Machine and the dc Compound Wound Machine. [2] Speed Range 0-3000 rpm [3] Provides up to 300W Output [4] Adjustable IR Compensation control for improved speed regulation. [5] Used as a drive when testing generators [6] Acceleration and Deceleration control. [7] Supply 200-240V AC at 50/60Hz [8] Motor Earth Terminal	

5	**1**	**Electromagnetic Control Of Machines**
		
		[1] Designed as an add-on to the Power and Machines Lab described earlier, the system is a series of frame-mounted panels containing a selection of motor control components designed to allow the student to investigate the principles of Electromagnetic Control.
		[2] The system is compatible with the Electrical Power Engineering system specified earlier and be capable of controlling the transformers and rotating machines specified.
		[3] System comprises 5 components as follows:
		• Contactor panel:
		  • 3-phase isolating switch, fused at 5A
		  • Power Control pushbutton connecting 24V ac to contactors, relay and speed control circuits
		  • Contactor with thermal overload relay
		  • 2 contactors mechanically interlocked
		  • Control relay fitted with pneumatic timer
		  • Speed relay with adjustable speed threshold to 4,000 rpm
		  • 3 x 50Ω 100W power resistors
		• Control Pushbuttons:
		  • 3 x pushbuttons with contacts, 1 N/O and 1 N/C. One button mushroom head type, two flush head type
		  • Three indicator lamps, two white, one green – 24V/0.12A
		• Motor Switches:
		  • 3 x pushbuttons with contacts, 1 N/O and 1 N/C. One button mushroom head type, two flush head type
		  • 3 position selector switch, 1 / OFF / 2. 1 nd 2 positions are 1 N/O and 1 N/C contacts
		• Magnetic Pickup:
		  • Provides a single pulse train suitable for speed measurement
		  • Attaches to motor base and shaft of the machine under test
		  • Provides DC voltage or current output
		  • Output 64 pulses per revolution
		• Din-Din 5 pin Cable
		  • 1 M long
		  • Used to connect between a tachogenerator or magnetic pickup to an appropriate control panel
		
		[4] Assignments
		
		• Direct On Line Starters
		• Direct On Line (DOL) Starter, electromagnetic locally controlled
		• DOL starter: starting, inching & jogging
		• DOL Starter: Forward & Reverse operation
		• DOL Starter with dc injection
		• DOL Starter: Plug Braking
			
			 
			 
			 
			 

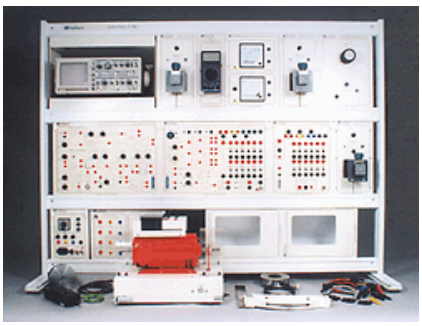
		• Star / Delta Starter • Primary Impedance Starter • DC Motor Starter • Dynamic Braking of a DC Motor	

6	**3**	**Dissectible Machines System** [1] The trainer includes power supplies, drive and control equipment, loading and instrumentation that are all provided in the form of panels which mount into a purpose-designed bench-standing frame, that can be easily slotted in and out as required. [2] The frame is constructed of an advanced, fibre-loaded, rigid plastics material that is electrically insulated for safety. [3] The characteristics of the machines that can be assembled closely represent those of their industrial equivalents. [4] The machine can be configured to make over 50 different machines, below is a list of the more common investigations and machine assemblies. • Introductory electromagnetism • Machine operating principles • Elementary ac & dc generators • dc series motor - with & without interpoles • dc shunt motor - with & without interpoles • dc compound motor - with & without interpoles • dc separately excited generator - with & without interpoles • dc series generator - with & without interpoles • dc shunt generator - with & without interpoles • dc compound generator - with & without interpoles • Single Phase ac induction motor, squirrel cage, 2 pole • Single Phase ac induction motor, squirrel cage, 4 pole • Single Phase ac series universal motor • Single Phase ac repulsion motor • Single Phase ac synchronous motor/generator, 2 pole • Single Phase ac synchronous motor/generator, 4 pole • Single Phase ac generator, rotating field • Single Phase ac generator, rotating armature • Three Phase ac induction motor, squirrel cage, 2 pole • Three Phase ac induction motor, squirrel cage, 4 pole • Three Phase ac synchronous motor, 2 pole • Three Phase ac synchronous generator, 2 pole • ac brushless generator • Stepper motors • Shaded pole induction motor • Split field series motor • Dynamic braking of a dc motor • Power factor correction of ac motors • Synchronisation • Synchronous motor characteristics • Pole-changing induction motor • dc shunt motor faults • 4 pole induction motor faults	 

		[5] Below is a list of the components in the basic machine; • Baseplate [1] Cast Aluminium alloy • Frame Ring [1] Aluminium Alloy [2] Fixed to base plate • Shaft [1] Stainless steel, anti corrosion [2] The shaft speed can range from very low values up to 3600 rev/min (for ac machines), or 5000 rev/min (for dc machines) according to the application. • Fixed and removable bearing housings [1] Aluminium alloy housings [2] Plain & self aligning Ball race bearings. • Wound Stator [1] Coils are wound from synthetic enamel-covered copper wire [2] Wrapped with a strong cloth-base tape. [3] Each has 'coil finish' and identification bands • Squirrel Cage Rotor [1] Coils are wound from synthetic enamel-covered copper wire [2] Housing made from electrical steel laminations riveted together. [3] Wrapped with a strong cloth-base tape. [4] Each has 'coil finish' and identification bands • Hand Crank • Centrifugal Switch • Coupling • Brush Holders and Brushes • Commutator/Slip Rings [1] made from electrical steel laminations riveted together. • Interpoles [1] made from electrical steel laminations riveted together. • Armature Poles and Hub [1] made from electrical steel laminations riveted together. • Field Poles [1] made from electrical steel laminations riveted together. • Armature, Field and Interpole coils [1] Coils are wound from synthetic enamel-covered copper wire [2] Wrapped with a strong cloth-base tape. [3] Each has 'coil finish' and identification bands • Compound Field Coils [1] Coils are wound from synthetic enamel-covered copper wire	

		[2] Wrapped with a strong cloth-base tape. [3] Each has 'coil finish' and identification bands • Tools and Hardware [6] AC Voltmeters & Ammeters. • Suitable for use in the study of synchronous generators or single and three phase supply measurements. • Provides both frequency and voltage measurements. • Meters are ideally suited to the applications of Synchronising generators and supplies. [7] The Electronic Single and Three Phase Measurements panel • Should measure all parameters on 3 or 4 wire, balanced, three phase systems. Measurements should include; • Voltage • Current • Power Factor • Watts • KVA • KVAR • KWH • Unit to be rated at 750V ac 5A per phase maximum. [8] Analogue voltmeters and ammeters • Moving coil DC Voltmeter • Voltmeter ranges 0-50, 0-250 and 0-500V dc • Ammeter ranges 0-1A, 0-5A and 0-10 A dc • Ammeter is fuse protected • Meters are to DIN 96 [9] DC Milliammeter, center zero. A dc milliammeter suitable for use in: • Electrical Circuit investigations • Motor/Generator setups • Giving direct indication of polarity and polarity reversals. • Ranges at least ±1mA, ±1A and ±5A [10] The electrical loading is with variable resistance loads and a resistor/capacitor unit for power factor correction • Resistive elements 3 x 68 Ohms minimum. • Capacitive elements 2µF, 4µF, 8µF and 10mF, Minimum. • Nominal ratings: Resistance: 50W each Capacitors: 400V (63V for 10mF) [11] Friction (Prony) brake • Fits directly onto the shaft of the machine. • Provides direct loading with integral measurement of the torque output of various motor assemblies. • Indicates torque output in either direction up to ±2nM Max. [12] Synchronising Lamps. • Provides basic synchronising by phase indicator	

		lamps grouped in a triangle. • Uses either lamps-bright or lamps-dark technique. • Provides a power switch to connect the systems together. • Can accommodate single or three phase systems. [13] Optical / Contact Tachometer. • Provides versatile measuring of shaft speed. • Non contact by photo sensing. • Direct shaft contact through conical rubber drive. • Measurement ranges: 99,999rpm Non-contact Max. 20,000rpm contact Max. [14] All of the equipment is supplied complete with courseware on CDROM, and includes theoretical information, practical assemblies, typical results and questions with typical answers. It is profusely illustrated and gives circuits, step-by-step assembly instructions and procedures [15] As the courseware for each assembly is stand- alone, users have the ability to select those relevant to their particular syllabus requirements and to create a practical and realistic workstation to suit courses at any level from vocational to graduate engineer [16] Weights & Dimensions (assembled in frame) Width 1000 Height 800 500 (allow extra bench space for machine and assembly area) Weight approx 40Kg	

7	**3**	**Thyristor and Motor Control.** [1] A frame mounted system for the study of power electronic devices and drives. [2] Includes all loads, instrumentation, circuit panels and supply controls required. [3] Frame is manufactured from a non-conductive composite for safety and strength. [4] Contains the following equipment; • Three Phase Supply panel • DC Shunt Machine • Variable resistive load 200Ω • Switched 3Φ resistive load • Switched capacitive load • Variable inductive load 700mH • Inertia load • Friction Brake • Moving Iron Voltmeter & Ammeter • Digital Voltmeter/ammeter • DC Tachogenerator • Optical / Contact tachometer • 4mm Patch lead set • 5 way DIN-DIN lead • SCR & Diodes panel • Firing circuits and bridges panel • Motor control circuits panel • System frame • Oscilloscope/computer housing • Lead storage bin [5] The components listed above combine to make a system to cover the following assignments; **Uncontrolled Rectification Circuits** • Single phase half wave • Single phase full wave • Three phase half wave • Three phase full wave **Controlled Rectification Circuits** • Single phase half wave • Single phase full wave • Three phase half wave, star connected supply • Three phase full wave, full controlled bridge Outputs from the various converters are measured for the average and rms values in conjunction with the various RLC load combinations. **Basic Firing Circuits** • Firing circuit requirements **Basic Motor Control** • Single phase full wave, uncontrolled bridge	

		• Single phase full wave, controlled bridge • The flywheel diode **Advanced Firing Circuits** • Thyristor phasing • Multipurpose firing circuits **Advanced Motor Control** • Feedback measurement • Full wave controlled bridge with speed Feedback • PI control • Full wave controlled bridge with armature voltage Feedback • Full wave controlled bridge with VI feedback **4 Quadrant Control** • Dual converter – single phase • Dual converter – three phase • Converter selection by control signal • Converter selection by load current • Converter selection by control signal and load current • Continuous and discontinuous current operation • Bi-directional speed and current control • Bi-directional control time behaviour • Regenerative braking • Effects of inertia on system performance **AC Power Control** • Single phase AC control • Three phase AC control • Burst fire control	

8	**3**	**20Mhz Oscilloscope.** [1] A general purpose 20Mhz analogue oscilloscope. [2] High intensity CRT with internal graticule [3] High sensitivity of 1 mV/div (DC to 5 MHz) The vertical axis sensitivity can be varied continually from 1 m/V div to 5 V/div with an attenuator. The 1mV/div sensitivity is especially useful in measuring very-low, complex signals. [4] Maximum sweep rate of 20 ns/div (x10 MAG) The sweep rate can be varied continually from 0.5 s/div to 0.2us/div. The sweep magnification (x10MAG) allows 10 times magnification in a one-touch operation enabling parts of a complicated waveform to be observed in more detail. [5] FIX sync The Fix sync function ensures a good locked waveform optimising synchronisation. This minimises trigger set up time. [6] Auto-focusing The auto-focusing function corrects focusing errors automatically. [7] One-touch TV sync The horizontal and vertical video signals can be observed with a one-touch operation. [8] Convenient VERT mode The VERT mode switches the sweep triggering sources automatically according to the vertical axis. When the vertical axis mode is CH1, the CH1 signal becomes the trigger source, CH2 mode selects the trigger source as CH2. In ALT mode, CH1 and CH2 signals can be triggered independently even when they have different frequencies. [9] One-touch ALT/CHOP switching The ALT and CHOP modes can be switched with a one-touch operation. This is convenient in phase-related observation of waveforms. [10] X-Y Mode Commences operation as an X-Y oscilloscope with CH1 as the Y-axis and CH2 as the X-axis. Z modulation provides external stimuli to the CRT (Intensity modulation) [11] Vertical axis signal output connector As this connector outputs the input signal at a rate of 50 mV/div, by connecting a frequency counter it is possible to measure the frequency of a very low signal while observing its waveform. **Weights & Dimensions:** 300 (W)x 140 (H)x415 (D) mm 7Kg (approx)	
9	**3**	**Function Generator.** The FG601 Function Generator is a general-purpose function generator having most of the features commonly required in the testing of electronic systems.	

		[12] Sine, square and triangle waveform [13] Frequency range 0.001Hz to 1MHz [14] Pushbutton selection of frequency [15] Main output of 20V pk to pk, 600 ohm [16] Switched and variable attenuation [17] TTL-compatible output [18] Continuous availability of triangle output at 2V [19] Voltage control of frequency (VCF) [20] Ergonomic case design [21] Operates from 200-250V or 100-125V **Waveforms:** Sine, square and Triangle, push button selected **Source impedance:** 600Ω **Amplitude:** 20V Pk-Pk open circuit **Stepped Attenuator:** Five, pushbutton selectable x1.0, x0.1, x0.01, x0.001 & x0 **DC Offset:** ±10 variable **Power Requirements:** 200/250 V or 100/125, 50 or 60 Hz Consumption 16VA **Weights & Dimensions:** 330x118x226mm 2.2Kg.	

10	**22**	**Hand Held Digital Multi Meter.** [1] 4300 Counts Circulating Record for MAX / MIN AVG and Normal [2] Capacitance, Frequency Measurement [3] Continuity Beeper/Diode Test [4] High Energy Fused for 10A Range [5] Auto-Hold, Relative set [6] Temperature, Inductance Measurement [7] Auto Power off **DC Voltage** Range 430mV, 4.3V, 43V, 430V, 1000V 5 ranges Accuracy ±(0.25% rdg + 1 digit) Input Impedance 10MΩ **AC Voltage (50Hz ~ 2kHz)** Range 430µV, 4.3V, 43V, 430V, 750V 5 ranges Accuracy ±0.75% rdg ~ ±1.5% rdg depends on range Input Impedance 10MΩ **DC Current** Range 430µA, 43mA, 430mA, 10A 4 ranges Accuracy ±0.5% rdg ~ ±2% rdg depends on range **AC Current (50Hz ~ 1kHz)** Range 430mA, 43mA, 430mA, 10A 4 ranges Accuracy ±1.0% rdg ~ ±2.5% rdg depends on range **Resistance** Range 430Ω, 4.3kΩ, 43kΩ, 430kΩ, 4.3MΩ, 43MΩ 6 ranges Accuracy ±0.3% rdg ~ ±1.5% rdg depends on range **Continuity Beeper** Buzzer sounds if conductance less than 50Ω± 30Ω **Diode Test** Test Current 1mA ± 0.6mA Open Voltage 3.5V typical **Capacitance** Range 4.3nF, 43nF, 430nF, 4.3µF, 430µF 5 ranges Accuracy ±(5.0% rdg + 10 digits) on all ranges **Frequency** Range 430Hz, 4.3kHz, 43kHz, 430kHz 4 ranges Resolution 0.1Hz Accuracy ±(1.0% rdg + 3 digits) @5V	

		Special Functions Inductance, Temperature, Logic Test **Power Source** Single 9V battery, NEDA 1604, JIS 006P, IEC 6F22 **Dimensions & Weight** 90(W) × 200(H) × 40(D) mm, Approx. 400g	

11	**1**	**Interactive whiteboard** [1] Electromagnetic, sealed sensing grid with passive transducer. [2] Resolution - 200 points per inch [3] Tracking Rate - 200 inches per second [4] Pointing Device - Cordless battery-free pen incorporating tipswitch and sideswitch for full 'mouse functionality' [5] Software - Supplied with ACTIVstudio; needs minimum system of 233 Mhz Pentium with Win 95/98/2000 or NT/Me/XP operating system and 32mb RAM [6] Interface - RS232 to host PC at up to 38.4kbs. ACTIVboard Plus has infra red and radio communications interface. [7] Standards Compliance - Compliance with all relevant CE requirements including EN 60950 (electrical safety), EN 55022 (RFI) [8] Environmental - 0-90% Humidity non condensing; -10O C to + 50OC temperature [9] Warranty - 3 years parts and labour [10] Size .110cm X 150cm 187.5cm diagonal 176cm X 126cm 40 kilos	

12	**1**	**1200 Lumen Projector** A 1200 ANSI Lumen project supplied complete with cable and ceiling mounting. The projector should be compatible with all software supplied with this laboratory.	

Budgetary Prices

Below is a budgetary price list for the items in this proposal.

Item	Qty	Part No.	Description	Unit FOB (GBP)	Total FOB (GBP)
1	1	61-400	Magnetics and Electromagnetics		
2	4	60-007	PowerLab with Virtual Instrumentation		
3	1	66-110	Variable Frequency Drive		
4	1	66-120	DC Motor Speed control		
5	1	65-020	Electromagnetic control of Machines		
6	3	62-005	Dissectible Machines Trainer		
7	3	70-003	Power Electronics Trainer		
8	3	CS4125A	20Mhz Oscilloscope		
9	3	FG601	Function Generator		
10	22	GDM393A	Digital Multimeter		
11	1	Activ-75	75” Interactive Whiteboard		
12	1	SE10	Digital projector		
				Total FOB	

For a quotation or more details please contact the sales office,

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