

Electrotechnical Technology Principles



Covering the relevant parts of City & Guilds 2330, levels two and three - Certificate in Electrotechnical Technology

In the UK today there is a large number of existing electrical installations and also a rapidly increasing number of new property developments that require the skills of well-trained and knowledgeable electricians.

To maintain and install new electrical systems and appliances requires an understanding of not only the relevant electrical standards involved but also the concepts and underlying principles that create the system or appliance in the first instance. Armed with this knowledge the qualified electrician is able to cope with the many technical issues that can arise in the working environment.

The City & Guilds scheme 2330 levels two and three certificate in Electrotechnical Technology requires that the appropriate relevant underpinning theoretical knowledge is understood and that the learning of these principles is carried out through 'hands-on experience'.

To meet these requirements Feedback Instruments through its many years experience in providing training solutions offers a product that fulfils many of the requirements to assist in delivering the C&G 2330 course by way of a modular training system that provides a low cost start up covering the level two requirements and the ability to expand the system to cover level three at a later date.

This brochure describes the modular 'hands-on' training system that aligns with the many tasks and assignments required to be performed that will go towards obtaining accreditation to the appropriate related NVQ.

The 60-070 C&G 2330 trainer has been conceived to reduce the number of equipment choices simplifying the route to selecting the appropriate product for your needs. The main choices are in instrumentation, either Virtual or Conventional and in Electrical machines being Industrial or Dissectible. There are additions to the system to consider, however these have been kept to a minimum.

System Benefits

- Low cost start-up
- Flexible, modular system can be easily extended
- High level of electrical and mechanical safety built-in
- Low cost installation - suitable for bench-top use
- Easily portable machines and system components
- Modular concept provides flexibility for individual requirements
- Choice of conventional or virtual instruments
- All products provided with in-depth teaching manuals

C & G 2330 curriculum mapping for 60-070

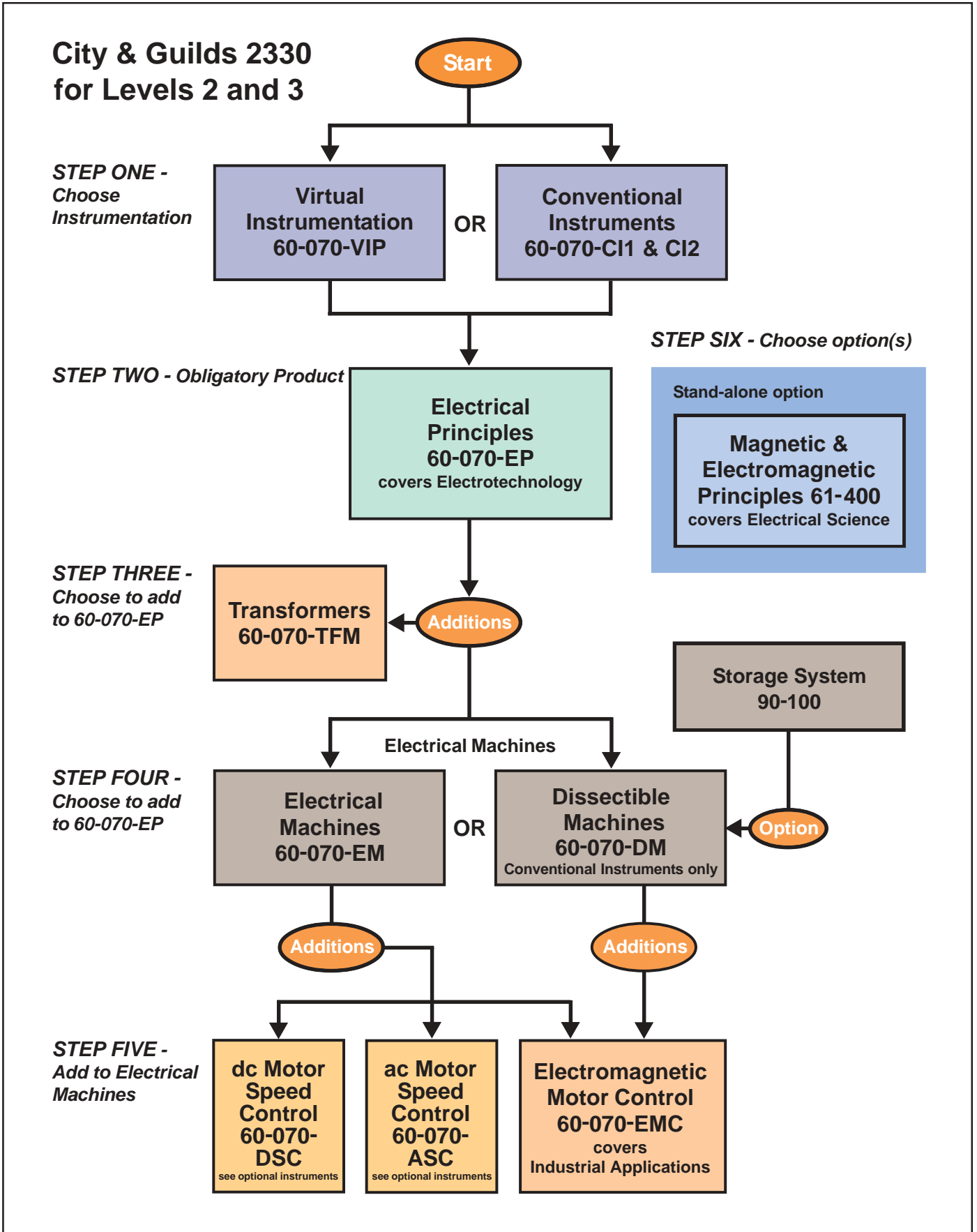
In both units of this qualification are a number of learning outcomes specifying a number of practical activities. They will be assessed by the use of an assignment set by the centre in accordance with the template supplied by the City and Guilds. The assignments will provide opportunities for the candidates to be assessed over a sample range of activities.

The following 2330 syllabus items are divided into their respective level, unit, and outcomes. These are necessary for the candidate to achieve their personal performance activity. The resultant level of candidate achievement will be graded. The candidates must pass all tasks within an assignment.

The level, unit and outcome only reflect that portion of the syllabus relating to the curriculum to be delivered to give the candidate the best opportunity of success in the science and principles subjects.

Level	Unit	Outcome	Syllabus/Scheme item number
2	2	1	1 and 4 to 7
2	2	2	Perform practical activities 1 to 3 and items 1 to 16
2	3	3	Perform practical activities 1 to 3 and items 1 to 7
2	5	3	1, 2, 17 and 18
2	7	1	2 to 5
2	7	5	1a to 1i
2	8	1	12 a-b to 19, 22, 24 and 25
2	9	1	1 and 11
3	1	4	1 to 7
3	1	5	1e to 1j and 3
3	1	6	1 to 4
3	2	1	11 and 12
3	2	2	5 to 7
3	4	1	2a, 2b, 7, 11 and 22 to 24
3	4	2	5 to 7
3	5	1	1a, 1b, 10 and 11
3	5	2	2 and 4
3	6	1	1d, 6, 12 to 15 and 25
3	6	2	5 and 6
3	7	1	1, 3, 7, 10 and 11
3	7	2	2 and 4 to 7
3	8	2	5a to 5g, 6 and 7
3	9	2	4 to 6
3	12	1	1 to 7
3	12	2	1 to 6
3	13	1	1, 2, 5 to 8 and 10
3	13	2	1 and 4

Electrotechnical Technology Principles



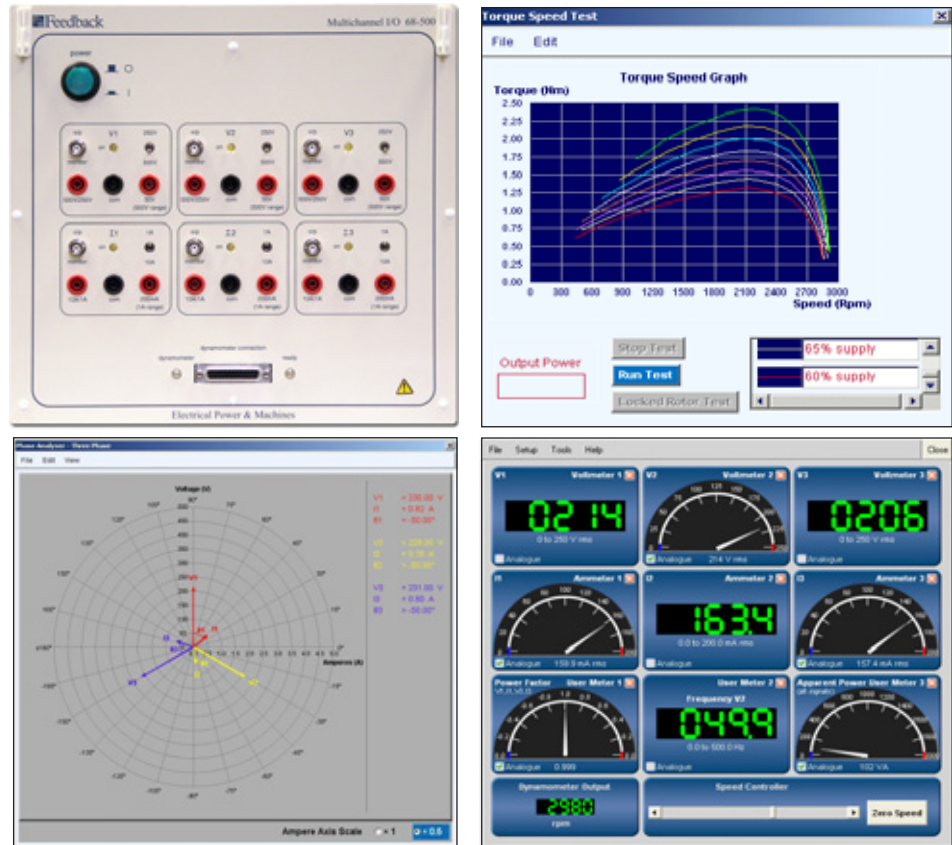
Virtual Instrumentation 60-070-VIP

Software Features

- Computer based machines testing system
- Displays up to nine selectable meter windows
- Choice of meter functions
- Analogue or digital virtual meter
- User definable meters
- Real-time plotting
- Four separate graph plots simultaneously
- Graph plotting with multiple functions
- Data export facility
- Transient recorder
- Browser based software

Hardware Features

- Purpose built, multi-channel I/O unit
- Six isolated channels
- Three voltage and three current inputs
- ac and dc measurements
- 50V - 500V ranges
- 0.2A - 10A ranges
- Six isolated oscilloscope monitoring points
- PC USB interface included



The Virtual Instrumentation 60-070-VIP comprises the 68-500 Multichannel I/O Module which is connected to a PC via a USB Interface and a software package which is supplied with a suite of virtual instruments.

The 68-500 has inputs for up to three ac or dc voltages and up to three ac or dc currents. These inputs are isolated from each other and each includes a single ended monitoring point so that waveforms can be studied using a conventional low cost oscilloscope. In addition a 25-pin socket is used to connect the 68-500 to the Torque/Speed Controller (68-441), which is part of 60-070-EM. This connector is used to read and control Torque & Speed requirements and allows Torque & Speed measurement via the PC.

The standard virtual instrument screen provides nine analogue or digital meters (three voltmeters, three ammeters and three user defined meters) plus a display of Torque and Speed and a slider to allow loading of a machine via the PC. Instrument settings can be saved for later use.

In addition to the meters the software provides very powerful plotting features. Any measured or calculated parameters (eg. Torque and Speed or Power Factor and Current) can be plotted against each other. Multiple plots can be included on one set of axes to obtain a family of curves at perhaps different voltages and up to four graphs can be displayed simultaneously. Data can be saved or exported.

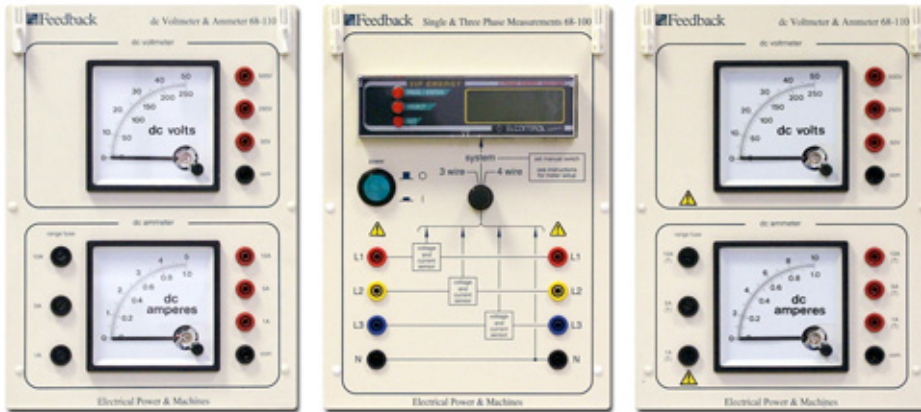
A Phasor Diagram (shown above) graphically shows the real-time relationship between the various three phase voltages and currents.

A Transient Recorder allows plotting of in-rush current and starting characteristics.

Conventional Instruments option

Conventional Instruments 60-070-CI1 and CI2

Conventional Instruments 60-070-CI1

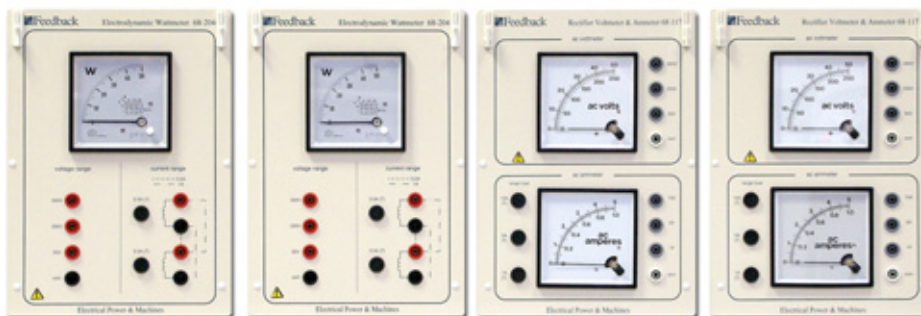


Various Measuring Instruments are required in order to perform the full range of experiments described in the teaching manual. These can be conventional meters, virtual instruments or a combination of the two.

The use of conventional meters is highly relevant in the field of Electrical Power and is both industrially relevant and provides good practice.

The range of high quality conventional instruments available for use with the 60-070 includes pointer type meters and a multi-functional single and three phase digital measuring system. All instruments are mounted within the frame system. The accuracy class of the pointer instruments is typically 3% which allows for precision measurements and the ability to measure small variations on line voltages and currents.

Conventional Instruments 60-070-CI2



To perform the full range of experiments for Electrical Principles 60-070-EP and for the additional products available, a wide range of conventional instruments are required.

The instruments consist of two ac Voltmeter/Ammeters, two ac/dc Electrodynamic Wattmeters and two dc Voltmeter and Ammeters.

Features

- Electronic single and three phase measurements
- Long scale style dc voltmeter and ammeter
- High accuracy industrial style analogue instruments
- Fuse protected current input ranges

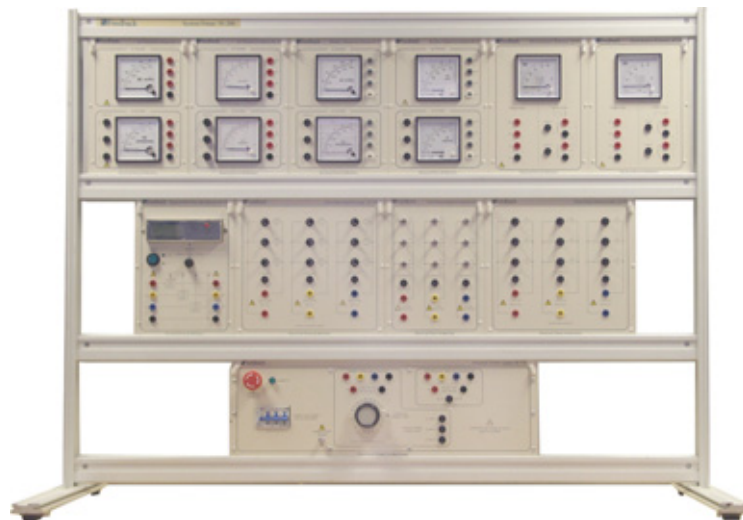
Features

- Two wattmeters for three phase power measurement
- Selectable voltage and current wattmeter ranges
- Multi-range voltmeters and ammeters
- Fuse protected current input ranges

Electrical Principles 60-070-EP

Curriculum Coverage

- **Resistive Network**
- **Construction**
- **Patching Familiarisation**
- **Current and Voltage**
Current Flow in Circuit
Voltage Measurement
- **Resistance and Ohm's Law**
Effect of Resistance
Resistance, Voltage and Current Relationship
- **Resistors in Series & Parallel**
Resistors in Series
Resistors in Parallel
- **Resistor Networks**
Current Law
Voltage Law
- **Power**
Voltage & Current Relationship to Power
Power Transfer
- **ac Theory**
ac and dc Comparison
Characteristics of a Sine Wave
- **Resistive Circuit at ac**
Current and Voltage Phase Relationship
- **Capacitive Circuit at ac**
Current and Voltage Phase Relationship
Reactance in Capacitive Circuit
Calibration of Capacitors
Capacitors in Series
Capacitors in Parallel
- **Inductive Circuit at ac**
Current and Voltage Phase Relationship
Reactance in Inductive Circuit
Calibration of Inductors
Inductors in Series
Inductors in Parallel
- **Combinations of Load Elements**
Resistor and Capacitor in Series
Resistor and Inductor in Series
- **Power in ac Circuit**
Component Power Dissipation
- **Three Phase Voltage and Current Relationships**
Voltage Relationships in a Balanced Star Supply
Star Load
Current Relationships in a Balanced Star Supply
Delta Load
- **Balanced Three Phase Resistive Load in Star and Delta Connections**
Power & Power Factor using Star Load
Power and Power Factor using Delta Load
- **Three Phase Sequence Determination**
Three Phase Sequence Determination



Either Electrical Principles with Conventional Instruments C11 & C12 or . . .



. . . Electrical Principles with Virtual Instrumentation (monitor and keyboard not included)

Electrical Principles 60-070-EP is a teaching system covering the fundamentals of electrical power teaching in dc, single phase and three phase circuits and systems. It can be used with either Virtual Instrumentation or Conventional Instrumentation and is supplied with manuals and laboratory notes on CD. They provide a step-by-step guide to setting-up and carrying-out the assignments associated with either system.

The system consists of system frame, power supplies, Three-phase Switched Capacitor Load 67-212, Three-phase Switched Inductor Load 67-312 & Three-phase Resistor Load 67-142. Instrumentation, either virtual or conventional is required provided by 60-070-VIP or 60-070-C11 and C12. The system provides a comprehensive introduction to dc, single and three-phase circuits.

Curriculum coverage includes Ohm's law, series and parallel circuits, resistance, reactance and impedance, phase relationships, balance loads and dc & ac power.

All the modules fit into a purpose designed, bench-standing frame and can be slotted in and out as required.

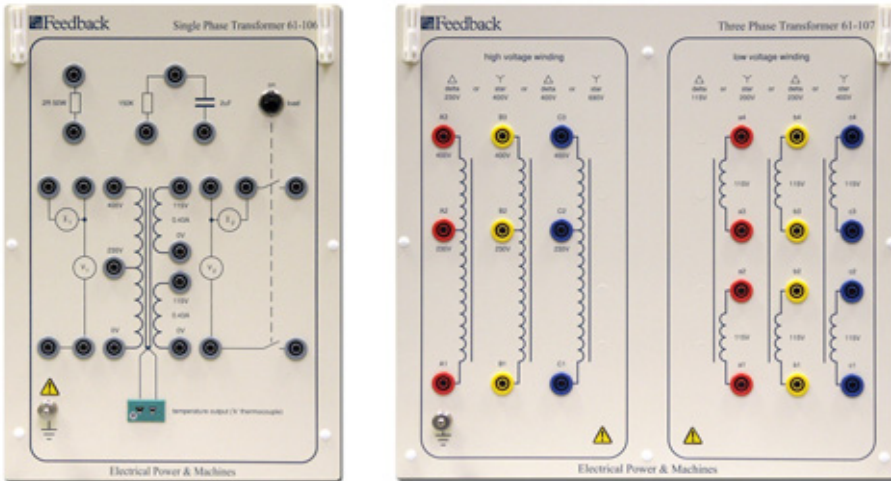
Safety has been paramount during the development of this system and every effort has been made to protect both the user and the equipment. Safety 4mm sockets are used throughout for interconnections.

The frame is constructed of an advanced, fibre-loaded, rigid plastic material that is electrically insulating for safety.

In order to make full use of the system some additional measuring instruments are required. Feedback can supply both conventional or PC-based meters as described on the previous pages and referenced in the experimental manual. Alternatively any suitable instruments can be used although experimental procedures might be slightly more difficult to follow in certain instances.

Electrical Science - Stand-alone system

Single & Three Phase Transformers 60-070-TFM



The TFM Transformer option provides two additional modules; the 61-106 Single Phase Transformer and the 61-107 Three Phase Transformer. Each is fully enclosed for safety and electrically protected. Front panel mimic diagrams simplify experimental connections.

Curriculum is provided for a comprehensive Transformer course covering Voltage and Current ratios, turns ratios and step-up and step-down operation, no-load and on-load performance, auto-transformers, star, delta, open-delta and zig-zag windings primary-secondary phase relationships and efficiency.

In addition to the instrumentation options CI1 and CI2 or Virtual, a digital multimeter with thermocouple type K input is required for use with 61-106.

Curriculum Coverage

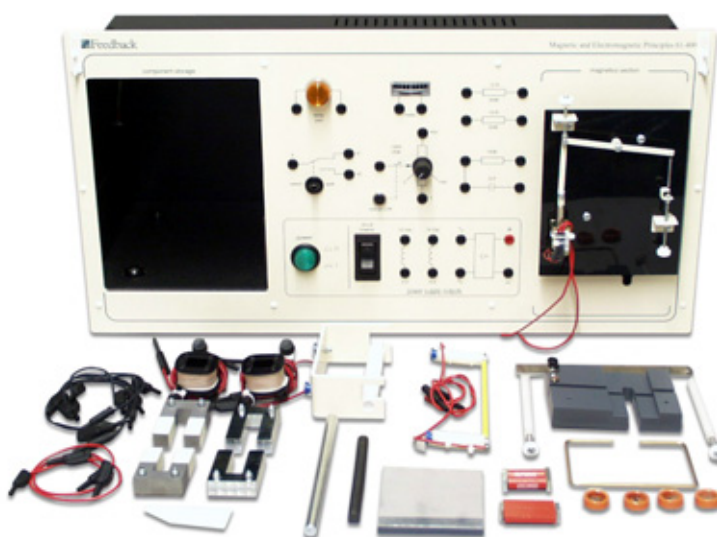
Single Phase Transformers

- Voltage and current ratios, turns ratio, step-up, step-down
- Voltage and current waveforms
- Winding polarity, series and parallel connection
- On-load characteristics, voltage regulation
- Auto-transformer, transformers in parallel, current transformer

Three Phase Transformers

- Winding polarity, connecting Star, Delta, Open Delta and Zig-Zag secondary windings
- Voltage & 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

Magnetic & Electromagnetic Principles 61-400



The frame or bench-mounted panel comprises a series of magnetic and electromagnetic components, which allow the investigation of a wide range of magnetic and electromagnetic principles. The magnetic components supplied are:

- | | | |
|-----------------------------|------------------------|------------------|
| ■ Bar magnets | ■ Four compasses | ■ Wound coils |
| ■ dc solenoid | ■ Iron & ferrite cores | ■ Laminated core |
| ■ Fixed & moving conductors | | |

Curriculum Coverage

- Magnetic fields of permanent magnets
- Flux paths of cores
- Magnetic materials, coefficients, BH curves
- Electromagnetics, fields around a wire and coil
- Motor and generator principles
- Mutual coupling
- Transformer principles

Electrical Machines 60-070-EM

Features

- Industrial style dc, single and three phase machines
- Supplied with comprehensive Torque/Speed measurement system
- High level of electrical and mechanical safety
- Quick and easy machine coupling
- Multi-output dc, single and three phase protected power supply

Curriculum Coverage

dc Motors and Generators

- dc Shunt Motor
- dc Series Motor
- dc Compound Motor
- dc Separately Excited Motor
- dc Shunt Generator
- dc Compound Generator
- Separately Excited dc Generator

ac Motors and Generators

- Series Universal Motor
- Single Phase Induction Motor - Capacitor Start/Induction run
- Three-phase Induction Motor
- Three-phase Synchronous Motor
- Three-phase Synchronous Generator

Motor & Generator Tests

- Input power
- Output power
- Peak torque output
- Torque/speed and efficiency characteristics
- Synchronous speed
- Power factor

Safety

All electrical machines in the 60-070 series are fitted with fully shrouded electrical connectors, shaft guards, alignment pins and quick-fasten and release mechanical catches to retain coupled machines.

The Electrical Machines 60-070-EM provides an introduction to the study of Electrical Machines which will be sufficient for the many requirements of City and Guilds 2330 and can be extended at any time by adding the Electromagnetic Motor Control 60-070-EMC Industrial Applications.

A detailed manual providing both theory and experimental procedure is provided in hard copy and electronic formats to help the student gain a working understanding of the subjects listed.

Universal Motor 63-100



The Universal Motor is a simple, versatile and very widely used motor which can operate using a dc supply or a single phase ac supply. Comparison is made between the operation using the ac and dc supplies and the need for a compensation winding is shown. Torque speed and efficiency curves as well as shaft reversal are some of the investigations made. A mimic on the terminal box shows the motor configuration.

dc Compound Wound Machine 63-120



The dc compound machine is essentially three machines in one, consisting of an armature and two individual field windings, series and shunt that can be interconnected to provide a third connection namely compound. It is also possible to connect the windings to configure a separately excited field machine. Not only are several motor configurations possible but also dc generators in their various forms may also be configured and tested. Connections are provided on a mimic panel mounted above the motor for the two separate fields, series and shunt and the armature. This arrangement allows ease of connection for the various motor or generator configurations possible.

Single phase Induction Motor-Capacitor Start/Induction Run 64-110



The Single Phase Induction Motor is one of the most commonly applied motors found in numerous industrial and domestic appliances. They consist of a main and start winding that requires the addition of a capacitor to start the motor. These windings and capacitor connections are shown on a mimic panel mounted on top of the motor. Exercises to investigate the torque/speed characteristic, starting requirement and the effect of the start capacitor on torque output are some of the tests carried out.

Three-phase Induction Motor - Squirrel Cage, Dual Voltage 64-501



The Three-Phase Squirrel cage Induction Motor finds numerous industrial applications due to its high reliability and low manufacturing cost. Ratings from 100W to tens of kilowatts are available for heavy industrial applications.

It is considered to be the ac equivalent to the dc shunt motor due to its near constant torque/speed characteristic. A mimic panel mounted on top of the motor depicts the three separate windings, one for each phase. They can be configured as Star or Delta connections. The study of this particular motor covers Star or Delta power connections and forward and reverse operation, star/delta starting, torque/speed and efficiency test.

Electrical Machines

Electrical Machines 60-070-EM

Manual Swinging Field Dynamometer 67-502



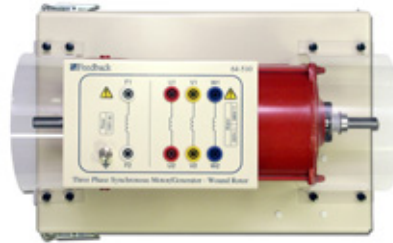
Used in conjunction with the 68-441 Torque/Speed panel. A strain gauge beam is used for torque measurement that provides torque values in both torque and speed modes. Also provided is the facility to carry out locked rotor tests by means of a mechanism that prevents the shaft from rotating, being held and allowed to move in sympathy with the swinging field of the dynamometer machine. An integral tachogenerator is used for speed measurement, both torque and speed signals connect to the 68-441 along with the machine field and armature connections.

Torque/Speed Control Panel 68-441



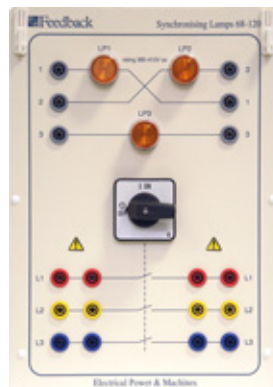
Used in conjunction with the Swinging Field Dynamometer 67-502 the panel provides all the necessary controls and metering for manual measurement of torque and speed values. Two variable controls in the torque mode are used to load the motor under test with either constant torque or torque proportional with speed type loads. When operating in the speed mode only one variable control is used to set the desired speed value. A digital display can be switched to display either torque or speed values. Protection is provided by a 'power interlock' system that prevents operation if the 67-502 is not fully connected. Control over the dynamometer system can be exercised by computer through a multi-way connector that requires interconnection to the 68-500 Multi-channel I/O panel.

Three Phase Synchronous Machine 64-510



The Three Phase Synchronous machine is mainly used for power generation and can be found in power generation plants all over the country to supply both domestic and industrial users with electricity. One of its characteristics that is extremely useful in power distribution systems is the ability to control power factor through variation of the rotor current. The machine windings are brought to a mimic panel that depicts the rotor and stator connections that are three separate windings to allow for star or Delta connections. As well as its operation as a three phase generator it can be run as a synchronous motor providing constant speed output and the ability to control power factor. The study of this machine covers its use as a motor and generator, starting requirements, synchronisation, on load and no load characteristics and its characteristics as a synchronous capacitor or inductor are some of the topics covered.

Synchronising Lamps 68-120



The Synchronising Module shows how the Three Phase generator can be synchronised to the existing power supply. The versatility of the 60-070 allows sophisticated experiments to be performed, such as, running the machine up to synchronous speed, synchronising as a generator, changing to synchronous mode to a motor and studying the characteristics and pull-out torque.

Features for 64-510

- Mimic diagram of motor windings
- Realistic industrial frame size
- Electrical and mechanical protection

Curriculum Coverage

- Open circuit test
- Short circuit test
- Effect of speed variation on output voltage and frequency
- Synchronisation procedure
- Operation of a synchronous machine
- Voltage regulation of a synchronous machine
- Variable reactor V curves

Shaft Coupling and Key 68-703



Couples 63 & 64 series motors to motor/generator for multi-machine experiments. 12mm shaft to 12mm shaft.

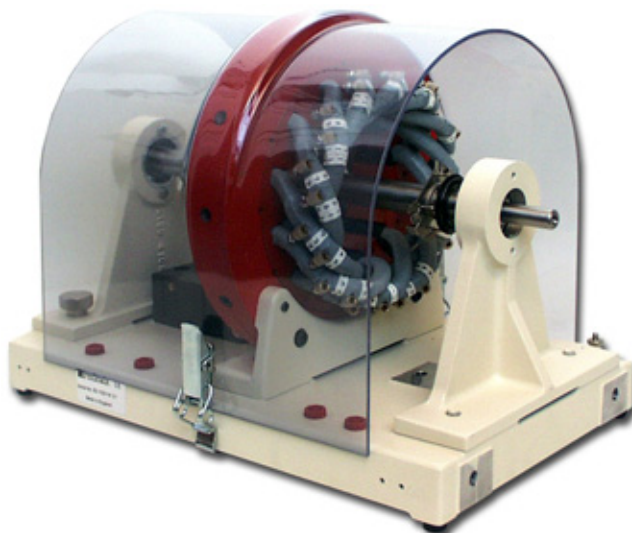
Dissectible Machines 60-070-DM

System components

- Baseplate
- Frame ring
- Shaft and coupling
- Fixed and removable bearing housings
- Wound stator
- Squirrel cage rotor
- Hand crank
- Centrifugal switch
- Brushes and brush holders
- Interpoles
- Commutator/slip rings
- Armature poles and hub
- Field poles
- Compound field coils
- Tools and hardware
- RC load unit
- Armature, field & interpole coils
- Control switches
- Component tray
- System frame
- Patch leads

Curriculum Coverage

- Elementary ac and dc generators
- dc series motor and generator
- dc shunt motor and generator
- dc compound motor and generator
- Single phase ac series universal motor
- Single phase ac repulsion motor
- Single phase ac synchronous motor/generator
- Single phase ac generator
- Three phase ac induction motor, squirrel cage, 2 pole and 4 pole
- Three phase ac synchronous motor and generator
- ac brushless generator
- Stepper motor
- Shaded pole induction motor
- Split field series motor
- Dynamic braking of a dc motor
- Power factor correction of ac motors
- Synchronous motor V curve characteristics
- Pole-changing induction motor
- dc shunt motor faults
- Four pole induction motor faults



The Dissectible Machine components allow over fifty machine assemblies to be built, covering a wide range of ac and dc single and 3-phase motors and generators.

The individual parts of the Machine assembly can be identified prior to completion of the full assembly.

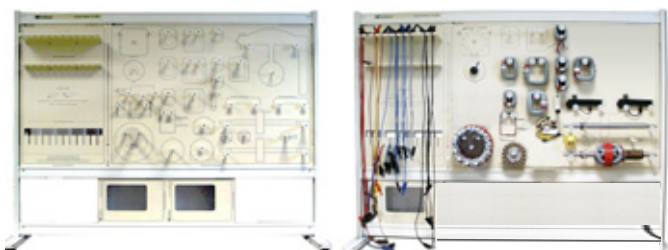
The assembled machines use low voltages, have protected rotating parts, and operate at relatively low power and voltage levels. Nominal operating voltages are 50V dc and 125V ac.

The Instruction manual details the procedure for the machine assemblies with wiring diagrams used to interconnect the units. Each assignment contains an aim and objective and is supported by theory.

The components are used to study subjects that range from the principles of magnetic circuits and electrical machine theory through to three-phase synchronous machines.

Students are able to see clearly the component parts of the machine and how they are interconnected, both electrically and mechanically.

With the addition of power supplies, metering, electrical and mechanical loads, the assembled machine can be operated and tested.



Optional Dissectible Machines Storage System 90-100



Control Switches 65-130

Variable ac/dc Supply 60-121



Resistor Capacitor Unit 67-190

Variable Resistance 67-113



dc Milliammeter, Centre zero 68-113

ac Volt and Frequency Meter 68-121



Synchronising Lamps 68-120

Hand held Tachometer 68-470



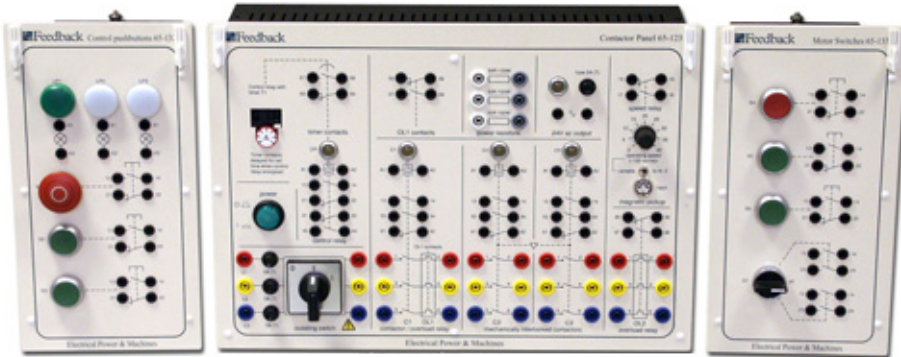
dc Variable Speed Drive 63-500 or 501



Prony Brake 67-470

Industrial Applications

Electromagnetic Motor Control 60-070-EMC



The use of power relays to provide a switched sequence of events for starting, stopping, forward and reversing of electrical machines has been traditionally carried out by Electromagnetic control gear. The application of these devices is widely used today and therefore the principles need to be understood.

The Electromagnetic Motor Control 60-070-EMC provides study methods and terminology associated with the implementation of control devices in some of the most commonly used circuits for control of ac and dc machines, to a level that can be understood by both maintenance engineers and technicians alike.

The equipment consists of a wide range of control gear that is provided on three panels. The main panel has electromagnetic contactors, and the other two have pushbutton and rotary switch gear and indicator lights.

A Magnetic pick-up is provided that fits onto the motor being controlled for measurement of shaft speed.

Curriculum Coverage

- DOL starter, electromagnetic, locally controlled
- DOL starter, starting/inching/jogging
- Star/Delta starter
- Primary impedance starter
- DOL starter: Forward/Reverse operation
- DOL starter with dc injection braking
- DOL starter with plug-braking
- dc motor starter
- Dynamic braking of a dc Motor
- Introduction to switchgear
- Motor configurations



Magnetic pick-up

ac & dc Motor Speed Control 60-070-ASC & 60-070-DSC



The ASC ac Motor Speed Control and DSC dc Motor Speed Control options extend the curriculum to include a comprehensive introduction to Power Electronics and ac & dc Motor Drives. They each comprise one additional module, the 66-110 Variable Frequency Drive or 66-120 dc Motor Speed Controller. Experiments are performed using the 64-501 Three Phase Squirrel Cage Motor for ac, and 63-120 dc Compound Wound Machine for dc control.

The 66-120 panel has separate Field and Armature connections that are protected by high speed fuses. Motor protection is by an internal current limiting circuit.

For both panels the front panel controls allow the variation of: Set Speed, Minimum Speed, IR Compensation and Acceleration/deceleration Time. Voltage boost is available for the 66-110 panel only.

NB - these panels require the use of the optional instruments shown on the back page.

ac Curriculum Coverage

- Basic Theory
- Control Functions
- Inverter Voltage Waveforms
- Carrier Frequency
- Inverter Current Waveforms
- Frequency, Speed, Current and Motor Voltage
- Torque/Speed test at various frequency settings
- Voltage Boost
- Voltage/Frequency (V/F) characteristics

dc Curriculum Coverage

- Thyristor dc motor control principles
- Motor voltage and current waveforms
- Speed regulation with and without phase angle control
- Phase angle versus motor speed
- Effect of feedback voltage on speed regulation
- Current limit control
- Torque/speed performance

Optional Instruments

In order to perform all the experiments for ac and dc Motor Speed Control the following instruments are required.

Voltage and Current Monitor 68-150 (2 sets required)

- For use where isolated voltage and current waveform measurements are required
- Precision four terminal shunt current monitor
- Shunt output isolated via voltage probe
- Probes output connects directly to a scope for safe monitoring



The following instruments are also required for ac Motor Control when using the 66-110 if not available in the laboratory:

ac Voltmeter and Ammeter 68-111

- A rectifier voltmeter and moving iron ammeter
- Suited to the measurement of variable frequency drives and ac supplies
- Rectifier voltmeter range 0 -250V and 0 -500V ac
- Moving iron ammeter range 0 -3A, fuse protected



Ordering Information

Virtual Instrumentation	60-070-VIP
Conventional Instruments	60-070-CI1
Conventional Instruments	60-070-CI2
Electrotechnology	
Electrical Principles	60-070-EP
Electrical Science (stand-alone)	
Magnetic and Electromagnetic Principles	61-400
Transformers	
Transformers	60-070-TFM
Electrical Machines	
Electrical Machines	60-070-EM
Dissectible Machines	60-070-DM
Dissectible Machines Storage System (optional)	90-100
Industrial Applications Additions	
Electromagnetic Motor Control	60-070-EMC
ac Motor Speed Control	60-070-ASC
dc Motor Speed Control	60-070-DSC
Voltage & Current Monitor	68-150
ac Voltmeter & Ammeter	68-111

Three Phase Earth Leakage Breaker 60-140-1

This unit is for use in systems where earth leakage breakers are not provided as part of the laboratory electrical installation but overcurrent protection is installed.

- Provides protection against the hazard of electric shock
- Suitable for connection to three-phase, 5 wire systems
- Four pole, 30mA trip, earth leakage breaker
- Three phase power 'on' indicators
- Single phase outlets on front and rear
- Safety earth terminals
- Three-phase output on rear panel for use with 60-105



Ordering Information

Three Phase Earth Leakage Breaker	60-140-1
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