Unit 30: Medical Instrumentation

Unit code: M/502/5575
QCF Level 3: BTEC National
Credit value: 10
Guided learning hours: 60

Aim and purpose

The aim of this unit is to enable learners to develop, through a practical approach, an understanding of the important principles and techniques applied in medical instrumentation. Learners will investigate transducers and sensors, processing circuits, how display and recording units are used and how medical instrumentation is maintained.

Unit introduction

This unit will give learners a basic understanding of the principles and techniques applied in medical instrumentation. It deals initially with the different types of transducers, sensors and input circuits that are used in the measurement of physiological signals.

This unit also covers electrical safety and the electrical isolation circuits that are used to protect the patient from any electrical hazards presented by the medical instrumentation system. It then considers the processing of the electrical signals produced by the transducers, for example amplification and analogue to digital conversion.

Learners will then investigate the different types of display devices used in medical instrumentation, considering advantages and disadvantages of different types. Finally, this unit covers calibration procedures including the calibration of test equipment and the use of digital technology to correct the deviation of real transducers from their ideal characteristics.

The emphasis of this unit is on the application of instrumentation in medical science using realistic examples from the work environment.

Learning outcomes

On completion of this unit a learner should:

1 Be able to investigate the use of transducers and sensors to take physiological measurements

2 Be able to demonstrate the processing used in medical instrumentation

3 Be able to investigate how display and recording units used in medical instrumentation circuits operate

4 Be able to investigate how medical instrumentation circuits are maintained and calibrated.

Unit content

1 Be able to investigate the use of transducers and sensors to take physiological measurements

Types of transducers: transducers for measuring eg pressure, temperature, gas flow, fluid flow, electrical conductivity; used in eg ventilators, dialysis machines

Sensors: electrodes eg ECG monitors; gas measurement eg oximeters/pulse oximeters, blood-gas analysers, oxygen sensors

Input circuits: measurement eg potential divider, Wheatstone bridge, voltage amplifier

Electrical safety and isolation: levels of electric shock; effects on muscle contraction, heart regulation, nervous system; electrical burns; isolation circuits eg opto-isolators, isolating transformers, isolating amplifiers

2 Be able to demonstrate the processing used in medical instrumentation

Processing circuits: eg filter circuits, op-amps as comparators, integrators and differentiators, analogue to digital conversion, sample and hold circuits, use of stored offsets, response characteristics

3 Be able to investigate how display and recording units used in medical instrumentation circuits operate

Displays: pen plotters; moving coil meters; different types of LED eg numerical, bar graph; LCD; CRT

Display systems: central station monitoring systems

Recording: pen plotters; magnetic tape; digital recording systems eg computer hard disk, flash memory

4 Be able to investigate how medical instrumentation circuits are maintained and calibrated

Maintenance: location of measuring systems; faults; errors; human error; procedures; checklists

Calibration: procedures; pre-test; quality assurance

Recording: accurate; detailed; responsible personnel; data recorded eg serial numbers of parts fitted, test equipment, patients tested; national standards

Assessment and grading criteria

In order to pass this unit, the evidence that the learner presents for assessment needs to demonstrate that they can meet all the learning outcomes for the unit. The assessment criteria for a pass grade describe the level of achievement required to pass this unit.

Assessment and grading criteria		
To achieve a pass grade the evidence must show that the learner is able to:	**To achieve a merit grade the evidence must show that, in addition to the pass criteria, the learner is able to:**	**To achieve a distinction grade the evidence must show that, in addition to the pass and merit criteria, the learner is able to:**
P1 carry out investigations into seven input transducers and sensors used in medical instrumentation, identifying in which physiological measurements they are used [IE1,2; TW1,2; SM3]	**M1** explain how transducers and sensors are used in physiological measurements	**D1** evaluate the use of different transducers to take physiological measurements, including invasive and non-invasive techniques
P2 explain the risks from electric shock in the operation of isolation circuits		
P3 demonstrate the purpose of processing circuits used in medical instrumentation	**M2** explain the operation of processing circuits	**D2** compare the use of analogue and digital processing circuits
P4 carry out investigations into the types of display units used in medical instrumentation [TW1,2; SM3]		
P5 explain what is meant by central station monitoring systems	**M3** explain the operation of display units used in medical instrumentation, including central station monitoring systems	**D3** compare and contrast the use of display and recording units on different medical devices and in different clinical environments
P6 report on the maintenance and calibration procedures carried out on medical instrumentation systems.	**M4** explain the principles and the need for calibration including that of the test equipment used.	**D4** evaluate calibration procedures and maintenance procedures, including the importance of documentation.

PLTS: This summary references where applicable, in the square brackets, the elements of the personal, learning and thinking skills applicable in the pass criteria. It identifies opportunities for learners to demonstrate effective application of the referenced elements of the skills.

Key	IE – independent enquirers	RL – reflective learners	SM – self-managers
	CT – creative thinkers	TW – team workers	EP – effective participators

Essential guidance for tutors

Delivery

The risk of electric shock from patient-connected equipment should be emphasised, along with the effects of electric shock on the human body. Manufacturers of electrical equipment produce a range of educational literature, service and calibration manuals which could be very useful in delivering the unit content.

Learners should understand that measuring systems often use mechanical systems and that faults in these systems can produce errors in measurement, for example blockages or leaks in flow measurement channels. Therefore, learners need to understand the need for regular maintenance and appreciate the risk of faults being introduced during maintenance due to human error. Learners must appreciate the need for clear maintenance procedures and checklists to minimise these risks.

Learners should understand the principle of calibration and be able to describe calibration procedures for transducers, measurement circuits, meters and displays in medical instrumentation systems. They should understand the need for calibration of test equipment and describe how equipment calibration is carried out.

Learners should also understand the need for accurate and detailed records, including who carried out the test, serial numbers of any parts fitted, serial numbers of all test equipment used, records of patients on whom the equipment is used and test equipment calibration records traceable to national standards.

For learning outcome 1, laboratory practicals could be used to investigate most of the sensors and transducers covered in this section. It is also important to take into account the practicality of using particular sensors and their impact on the patient. Tutors must emphasise the increased risk of electric shock that patient-connected equipment poses, including the patient condition and treatment which may impair or disable the patient's ability to respond to the danger.

For learning outcome 2, laboratory practicals can also be used to deliver some of the content of this section. The emphasis should be on the function of the signal conditioning circuits in context with the relevant medical equipment. The advantages of digital technology to correct imperfections in transducers' characteristics must be emphasised.

Learning outcome 3 can be delivered using case studies to investigate different display systems and considering their merits and limitations for their particular applications.

Case studies are an effective way of presenting learning outcome 4. Educational material and manufacturers' service manuals would be particularly useful to illustrate the section content with specific examples. Learners should be aware of the general principles of calibration, precision and accuracy and be able to apply this to specific case studies of medical equipment. As part of the delivery of the equipment records section, a simple database could be developed by learners.

Outline learning plan

The outline learning plan has been included in this unit as guidance and can be used in conjunction with the programme of suggested assignments.

The outline learning plan demonstrates one way in planning the delivery and assessment of this unit.

Topic and suggested assignments/activities and/assessment
Introduction to unit content and programme outline. Theory input: transducers and sensors are used to take physiological measurements. Practical activities: practical investigations of functions of various transducers and sensors. Learner activity: case studies of medical equipment. Learner home-study task: research medical applications of transducers and sensors to measure physiological signals (including possible hospital visit). Research impact of particular sensors on patients. Learning activity: compare with alternative methods of measuring physiological signals. **Assignment 1: Transducers and Sensors for Measuring Physiological Signals (P1, P2, M1, D1)**
Theory input: processing used in medical instrumentation. Practical activities: practical investigations of the function of signal conditioning circuits for particular sensors in context with the relevant medical equipment. Learner home-study task: research on advantages of digital technology compared with analogue technology (including possible hospital visit). **Assignment 2: Signal Processing Circuits (P3, M2, D2)**
Theory input: the operation of display and recording units used in medical instrumentation circuits. Learner activity: case studies to investigate different display systems and consider their merits and limitations. Learner home-study task: research the function of the central monitoring system. **Assignment 3: Display Systems (P4, P5, M3, D3)**
Theory input: maintenance and calibration procedures for medical instrumentation circuits – including test equipment. Learner activity: case studies of medical equipment to which are applied the general principles of calibration, precision and accuracy. **Assignment 4: Maintenance and Calibration of Medical Equipment (P6, M4, D4)**
Review of unit and programme of assignments.

Assessment

All the pass grade criteria must be met in order for learners to achieve this unit.

For P1, learners must investigate the function of transducers, sensors and their input circuits. They should also identify the physiological measurements that they are associated with. This evidence could be based on laboratory practicals and case studies of medical equipment. For P2, learners need to explain the risks of operating isolation circuits. For M1, learners must explain the operation of the transducers and sensors in terms of the underlying scientific principles when used to take physiological measurements. They must also explain the operation of input and isolation circuits. For D1, learners must evaluate the use of transducers to measure physiological signals in terms of accuracy, range, resolution, costs, risk/discomfort to patients etc. Where relevant, learners should compare alternative methods of measuring physiological signals.

For P3, learners need to demonstrate the function of processing circuits in the context of a medical device, including the conversion of analogue signals to digital signals for input to a digital control system. Evidence for this section could also be generated with a combination of laboratory practicals and case studies of medical equipment. For P4, learners must investigate display units used in medical devices. For M2, learners must explain the operation of processing circuits, including those used for signal conditioning, analogue to digital conversion and the use of stored offset information to correct the input from transducers. For D2, learners must compare the use of analogue and digital processing circuits for physiological signals.

To achieve P5 learners must explain what a central station monitoring system is. For M3, learners must explain the operation of display units including central monitoring systems. For D3, learners must compare and contrast different display types for displaying the physiological measurements in terms of response time, resolution, clarity etc. Learners must also compare traditional methods of recording physiological measurements with modern digital methods.

For P6, learners must know procedures of planned maintenance and records and describe calibration procedures. For M4, learners must explain calibration procedures for medical devices and test equipment. For D4, learners must evaluate calibration and maintenance procedures in terms of risk of introducing human errors, costs, comparison of calibrating amplifiers etc with simulated electrical signals or signals derived from real physiological parameters (for example by placing a thermistor in a substance at a known temperature, for example warm water). Learners must also describe the importance of keeping accurate records, for example when investigating accidents, in infection control, to facilitate tracing replacement components in the event of manufacturers recall, to trace calibration of transducers back to national standards or to identify any devices affected by the use of faulty test equipment.

Programme of suggested assignments

The table below shows a programme of suggested assignments that cover the pass, merit and distinction criteria in the assessment and grading grid. This is for guidance and it is recommended that centres either write their own assignments or adapt any Edexcel assignments to meet local needs and resources.

Criteria covered	Assignment title	Scenario	Assessment method
P1, P2, M1, D1	Transducers and Sensors for Measuring Physiological Signals	You have been asked to explain to colleagues the accuracy, range, resolution, costs, risk/discomfort to patients etc of a number of transducers and sensors used for measuring physiological signals.	Report on laboratory practicals investigating sensors and transducers, including risk assessments.
P3, M2, D2	Signal Processing Circuits	Some customers want to know about signal processing circuits for medical equipment.	Report on laboratory practicals involving signal processing circuits. Case studies of processing circuits used in context with the relevant medical equipment.
P4, P5, M3, D3	Display Systems	You have been asked to train new technicians and you want to ensure that they understand the display systems that are used in central station monitoring systems.	Case studies of different display systems, considering merits and limitations for their particular applications.
P6, M4, D4	Maintenance and Calibration of Medical Equipment	A report is required on the maintenance and calibration procedures managed by a hospital medical equipment team.	Evaluation of maintenance and calibration procedures.

Links to National Occupational Standards, other BTEC units, other BTEC qualifications and other relevant units and qualifications

This unit forms part of the BTEC Applied Science sector suite. This unit has particular links with the following units in the Applied Science suite:

Level 2	Level 3
Energy and Our Universe	Statistics for Science Technicians
Applications of Physical Science	Electrical Circuits and their Applications
Electronics in Action	Medical Physics Techniques
	Biomedical Science Techniques
	Electronics for Science Technicians

Essential resources

Learners need access to a medical library and the internet.

Employer engagement and vocational contexts

Visits to local hospitals and other medical/healthcare facilities and from their employees would be very valuable in delivering this unit.

The use of vocational contexts is essential for delivery and assessment.

Centres should aim to develop links with local hospitals and other medical/healthcare facilities where it is possible to observe a range of medical instruments in use.

Indicative reading for learners

Textbooks

Carr J J and Brown J M – *Introduction to Biomedical Equipment Technology* (Prentice Hall, 2000) ISBN 9780130104922

Jennings D, Nokes L D M, Turton B C H and Flint T – *Introduction to Medical Electronics Applications* (Butterworth-Heinemann Ltd, 1995) ISBN 978034061 4570

Journal

British Medical Journal

Websites

www.americanheart.org	American Heart Association
www.artp.org.uk	Association for Respiratory Technology and Physiology
www.bmj.com	British Medical Journal
www.innerbody.com	Human anatomy online
www.science-campus.com	The Science Campus

Delivery of personal, learning and thinking skills

The table below identifies the opportunities for personal, learning and thinking skills (PLTS) that have been included within the pass assessment criteria of this unit.

Skill	When learners are ...
Independent enquirers	[IE1,2] engaging in research and information gathering for applications that use sensors to take physiological measurements
Team workers	[TW1,2] carrying out investigations
Self-managers	[SM3] organising time and resources and planning action to produce reports on laboratory work and on processing circuits.

Although PLTS are identified within this unit as an inherent part of the assessment criteria, there are further opportunities to develop a range of PLTS through various approaches to teaching and learning.

Skill	When learners are ...
Independent enquirers	[IE3,4,6] planning and carrying out research into locations or sites they plan to visit, plus their own research into a variety of medical instruments
Creative thinkers	[CT3,5] trying different ways to tackle a problem, working with others to find imaginative solutions and outcomes that are of value
Reflective learners	[RL2,4] setting goals and targets within the planning of their work; inviting feedback from others in the group on their reports.

Functional Skills – Level 2

Skill	When learners are ...
ICT – Find and select information	
Select and use a variety of sources of information independently for a complex task	researching exploration, extraction and processing of resources
Access, search for, select and use ICT-based information and evaluate its fitness for purpose	planning for visits or planning a presentation
ICT – Develop, present and communicate information	
Enter, develop and format information independently to suit its meaning and purpose including: • text and tables • images • numbers • records	producing tables, graphs and maps as part of the report write-up stage following visits; incorporating photographs
Bring together information to suit content and purpose	bringing together information for assignments reports
Present information in ways that are fit for purpose and audience	producing reports on laboratory practicals and on maintenance/ calibration procedures written in appropriate formats
Mathematics	
Identify the situation or problem and the mathematical methods needed to tackle it	applying appropriate mathematical methods to measure accuracy, range, resolution, costs
Use appropriate checking procedures and evaluate their effectiveness at each stage	carrying out calculations accurately
Draw conclusions and provide mathematical justifications	evaluating solutions to problems solved through use of mathematical methods
English	
Speaking and listening – make a range of contributions to discussions and make effective presentations in a wide range of contexts	discussing hospital visits and lab work risk assessments presenting the result of research into chosen areas
Reading – compare, select, read and understand texts and use them to gather information, ideas, arguments and opinions	researching background information for hospital visits
Writing – write documents, including extended writing pieces, communicating information, ideas and opinions, effectively and persuasively	writing visit reports.