



**ZIMBABWE**

**MINISTRY OF HIGHER AND TERTIARY EDUCATION,  
INNOVATION, SCIENCE AND TECHNOLOGY  
DEVELOPMENT**

**HIGHER EDUCATION EXAMINATIONS COUNCIL  
(HEXCO)**

**NATIONAL DIPLOMA**

**IN**

**BIOMEDICAL ENGINEERING**

**MODULE: Medical Physics**

**PAPER NO: 654/23/M03**

**DURATION: 3 Hours**

**JUNE 2026 EXAMINATION**

**REQUIREMENTS**

**INSTRUCTIONS TO CANDIDATE**

**Answer any five (5) questions.**

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*This paper consists of 3 printed page.*

PAPER NO: 654/23/M03 – MEDICAL PHYSICS

QUESTION 1

- a) Describe the process of beam attenuation and half value thickness. (10 marks)
- b) Discuss the principles of radiological image formation. (10 marks)

QUESTION 2

Describe the interaction of radiation with matter, paying special attention to Photo- electric effect, Compton scattering and pair production. (20 marks)

QUESTION 3

- a) With the aid of a well annotated diagram, describe production of characteristic X-Rays. (10 marks)
- b) Discuss occupational exposure, public exposure and annual limits of radiation exposure. (10 marks)

QUESTION 4

- a) Describe the radiological emergency procedures. (10 marks)
- b) Outline the properties of detectors used in nuclear medicine. (10 marks)

QUESTION 5

- a) Identify image quality related problems in medicine. (12 marks)
- b) Describe the Acoustic properties of biological tissues. (4 marks)
- c) Explain Wave motion and propagation. (4 marks)

QUESTION 6

Describe radiation dosimetry measurement processes for calibration of medical radiation. (20 marks)

PAPER NO: 654/23/M03 - MEDICAL PHYSICS

QUESTION 7

- a) Outline the general framework for radiation protection. (10 marks)
- b) Describe the imaging instrumentation for planar, whole body SPECT and hybrid imaging. (10 marks)

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**NATIONAL DIPLOMA**

**IN**

**BIOMEDICAL ENGINEERING**

**MODULE: Biomedical Engineering Electronics PAPER NO: 654/23/M04**

**DURATION: 3 hours**

**JUNE 2026 EXAMINATION**

**REQUIREMENTS**

**INSTRUCTIONS TO CANDIDATE**

1. Examination consists six (6) questions.
2. Each question carries 20 marks.
3. Answer any five (5) questions.
4. Begin each question on a new page.

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*This paper consists of 5 printed pages.*

QUESTION 1

- a) Define the following h-parameters for a transistor in the Common Emitter (CE) configuration and state the units of each.
- i)  $h_{ie}$  (2 marks)
  - ii)  $h_{fe}$  (2 marks)
  - iii)  $h_{re}$  (2 marks)
  - iv)  $h_{oe}$  (2 marks)
- b) Explain why the h-parameter method of transistor analysis yields more accurate results than a simple  $\beta$ -based approach. (3 marks)
- c) Describe the principle of operation of the following op-amp circuits. For each circuit draw a clearly labelled diagram and write the output voltage expression:
- i) Differential amplifier (3 marks)
  - ii) Differentiator (3 marks)
  - iii) Integrator (3 marks)

QUESTION 2

- a) List two (2) types of thyristor-based switching devices and state one biomedical application for each. (2 marks)
- b) State the function of each building block of a Switched Mode Power Supply (SMPS). (6 marks)
- c) Describe the advantages of an SMPS over a linear power supply. (4 marks)
- d) Design an instrumentation amplifier using three op-amps to amplify the differential signal from a biomedical pressure sensor. The required differential gain is 500. Given that the two input op-amps each have  $R_f = 10k\Omega$ , calculate the value of the gain-setting resistor  $R_G$ . Also determine the output voltage if the differential input signal is 4mV. (8 marks)

QUESTION 3

- a) Describe the operation of the following voltage regulation techniques, drawing a circuit diagram for each.
- i) Zener diode shunt regulator (4 marks)
  - ii) Transistor series regulator (4 marks)
- b) An LM317 adjustable regular circuit has  $R_1 = 240\Omega$  and  $R_2 = 2.4k\Omega$ . Determine the output voltage using  $V_{out} = 1.25 (1 + R_2/R_1)$ , neglecting  $I_{ADJ}$ . (2 marks)
- c) A 78XX series regulator has a maximum output current of 1A and an input of 18V. If the load is  $15\Omega$  and the output is regulated to 12V, calculate the power dissipated by the regulator IC. (2 marks)
- d) Identify which IC from the 79xx series would be required to produce a  $-5V$  regulated output. (2 marks)
- e) State the Barkhausen criterion for sustained oscillation. (2 marks)
- f) For the Barkhausen criterion, identify the two conditions that must simultaneously be satisfied, and explain what happens to the oscillation if each condition is violated. (4 marks)

QUESTION 4

- a) Describe the principle of operation of the RC Phase Shift Oscillator. (4 marks)
- b) Calculate the frequency of oscillation for:
- i) An RC phase-shift oscillator where  $R = 12k\Omega$  and  $C = 8nF$  (3 marks)
  - ii) A Hartley oscillator where  $L_1 = 2mH$ ,  $L_2 = 3mH$  and  $C = 50pF$  (3 marks)
- c) State four (4) advantages of modulation in communication systems. (4 marks)
- d) Define amplitude modulation (AM). (2 marks)
- e) State the significance of the modulation index  $m$ , including the condition for over-modulation. (4 marks)

QUESTION 5

- a) Explain how an AM wave contains three (3) frequency components. (3 marks)
- b) Describe the demodulation process for:
- i) An AM signal using a diode envelope detector (include the circuit diagram and explain the role of the RC filter) (5 marks)
  - ii) An FM signal using a phase-locked loop (PLL) demodulator (explain how the VCO tracks the incoming FM signal). (5 marks)
- b) Determine the following for an FM transmission: carrier frequency  $f_c = 100\text{MHz}$ , frequency deviation  $\Delta f = 50\text{kHz}$ , highest modulating frequency  $f_m = 10\text{kHz}$ . Calculate:
- i) The modulation index  $\beta$  (2 marks)
  - ii) The bandwidth (2 marks)
  - iii) The total power in an AM wave if the carrier power is 800W and  $m = 0.8$  (3 marks)

QUESTION 6

- a) Solve using a 4-variable Karnaugh map (K-map) to minimise the Boolean function:  $F(A, B, C, D) = \sum m(0, 2, 3, 8, 9, 10, 11)$ . Draw the K-map, identify all groupings and write the minimised Sum-of-Products (SOP) expression. (4 marks)
- b) Design a BCD-to-seven-segment decoder for digit '5'. Write the Boolean expression for each of the seven segments (a – g) for the digit 5 and show how segments would be activated. (4 marks)
- c) Define sequential logic and distinguish it from combinational logic. Draw the truth table and logic symbol for:
- i) SR-Flip-flop (2 marks)
  - ii) JK Flip-flop (2 marks)
- d) Draw the circuit of the 4-bit Serial-In Parallel-Out (SIPO) shift register using D flip-flops and show the state of each flip-flop output after each clock pulse when the serial input sequence is 1011 (MSB first). (4 marks)

- e) Draw the logic circuit of a MOD-5 (divide-by-5) ripple counter using JK flip-flops. Produce the state transition table from 000 to 100 and explain how the counter resets to 000 after reaching count 5. (4 marks)

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**HIGHER EDUCATION EXAMINATIONS COUNCIL  
(HEXCO)**

**NATIONAL DIPLOMA**

**IN**

**BIOMECHICAL ENGINEERING**

**MODULE: Radiology Equipment**

**PAPER NO: 654/23/M08**

**DURATION: 3 hours**

**JUNE 2026 EXAMINATION**

**REQUIREMENTS**

**INSTRUCTIONS TO CANDIDATE**

**Answer any five (5) questions.**

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***This paper consists of 3 printed pages.***

QUESTION 1

- a) Describe the main functions of an x-ray machine. (6 marks)
- b) State the units used to measure radioactivity and identify what each unit measures. (6 marks)
- c) List the dangers associated with x-ray radiation exposures. (8 marks)

QUESTION 2

- a) Describe the working principle of an x-ray tube. (10 marks)
- b) Describe the safety precautions that must be observed when handling x-ray tubes. (10 marks)

QUESTION 3

- a) Define the following terms as used in medical ultrasound:
  - i) Wavelength (2 marks)
  - ii) Acoustic impedance (2 marks)
  - iii) Reflection (2 marks)
  - iv) Refraction (2 marks)
  - v) Piezoelectric effect (2 marks)
- b) Describe the applications of medical diagnostic ultrasound in two clinical areas. (10 marks)

QUESTION 4

- a) State and explain the function of any four (4) of the main components of a CT scanner. (8 marks)
- b) Describe the biological effects of CT radiation on the human body. (6 marks)
- c) Identify the environmental requirements that must be met when installing a CT scanner. (6 marks)

QUESTION 5

- a) Describe the purpose of calibration in CT equipment and outline the general steps followed during calibration. (10 marks)
- b) Describe the purpose of calibration in MRI equipment and outline the general steps followed during calibration. (10 marks)

QUESTION 6

- a) State any four (4) of the main components of an MRI machine and give their functions. (8 marks)
- b) Describe the safety precautions associated with MRI equipment, with specific reference to its unique hazards. (12 marks)

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**NATIONAL DIPLOMA**

**IN**

**BIOMEDICAL ENGINEERING**

**MODULE: Research Methods**

**PAPER NO: 654/23/M06**

**DURATION: 3 Hours**

**JUNE 2026 EXAMINATION**

**REQUIREMENTS**

**INSTRUCTIONS TO CANDIDATE**

**Answer any five (5) questions.**

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*This paper consists of 3 printed page.*

QUESTION 1

- a) Define the following terms as used in research:
- i) Research (2 marks)
  - ii) Research gaps (2 marks)
  - iii) Research problems (2 marks)
  - iv) Research scope (2 marks)
  - v) Literature review (2 marks)
- b) State the steps involved in the research process. (10 marks)

QUESTION 2

- a) Describe the characteristics of good research objectives. (10 marks)
- b) Describe the types of research designs. (10 marks)

QUESTION 3

- a) Explain the data collection methods used in research. (12 marks)
- b) Explain the importance of ethical consideration in data collection. (8 marks)

QUESTION 4

- a) Describe the methods of sampling used in research. (12 marks)
- b) Define the term data analysis. (2 marks)
- c) Explain the measures of central tendency. (6 marks)

QUESTION 5

- a) Distinguish between qualitative and quantitative data. (8 marks)

- b) Describe the following statistical distributions:
- i) Normal distribution (4 marks)
  - ii) Binomial distribution (4 marks)
  - iii) Poisson Distribution (4 marks)

QUESTION 6

- a) Describe the structure of a research report. (12 marks)
- b) Explain the importance of interpreting research results. (8 marks)

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**NATIONAL DIPLOMA**

**IN**

**BIOMEDICAL ENGINEERING**

**MODULE: Biomedical Engineering  
Embedded System 2**

**PAPER NO: 654/23/M07**

**DURATION: 3 Hours**

**JUNE 2026 EXAMINATION**

**REQUIREMENTS**

**INSTRUCTIONS TO CANDIDATE**

**Answer any five (5) questions.**

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*This paper consists of 4 printed page.*

PAPER NO: 654/23/M07 – BIOMETRICAL ENGINEERING EMBEDDED SYSTEMS 2

QUESTION 1

- a) State four (4) primary data types used in C++ programming. (4 marks)
- b) Describe the difference between a constant and a variable giving an example of each. (4 marks)
- c) Explain the concept of a function in C++ programming. (4 marks)
- d) Describe the purpose of the following control statements in C++
  - i) if – else statement
  - ii) for loop
  - iii) while loop
- e) Describe a pointer in C. (2 marks)

QUESTION 2

- a. Explain the concept of operator overloading in C++. (4 marks)
- b. Define the term microcontroller (2 marks)
- c. Identify four (4) elements/ components found in a microcontroller. (4 marks)
- d. Explain the architecture of the PIC 18F4550 microcontroller. (6 marks)
- e. Describe PWM as used in Microcontroller systems. (4 marks)

QUESTION 3

- a) Describe the following serial communication protocols:
  - i) UART (2 marks)
  - ii) SPI (2 marks)
  - iii) I<sup>2</sup>C (2 marks)
- b) State four biomedical sensors that can be interfaced to a microcontroller. (4 marks)

PAPER NO: 654/23/M07 – BIOMETRICAL ENGINEERING EMBEDDED  
SYSTEMS 2

- c) Explain the concept of an interrupt in a microcontroller system. (4 marks)
- d) Describe the function of a Real- Time Clock module when interfaced to a microcontroller. (2 marks)
- e) Explain the concept of debouncing as applied to switches in microcontroller systems. (4 marks)

QUESTION 4

- a) Describe the process of integrating a computer system with a microcontroller system. (6 marks)
- b) State the two (2) main types of software. (2 marks)
- c) Describe an operating system. (4 marks)
- d) Classify operating systems into their 2 categories and give one (1) example of each. (4 marks)
- e) Define the term application software and give two (2) examples.

QUESTION 5

- a) Explain the waterfall software life cycle model. (4 marks)
- b) Describe the following terms:
  - i) Software validation (2 marks)
  - ii) Software verification (2 marks)
- c) Define a PLC. (2 marks)
- d) State four (4) advantages of using a PLC over a relay logic system. (4 marks)
- e) Describe PLC scanning time with reference to the number of inputs and outputs. (2 marks)
- f) Describe the following PLC programming languages:
  - i) Ladder logic (2 marks)
  - ii) Statement list (2 marks)

PAPER NO: 654/23/M07 – BIOMETRICAL ENGINEERING EMBEDDED  
SYSTEMS 2

QUESTION 6

- a) Distinguish between DDC, SCADA and DCS. (6 marks)
- b) State two (2) practical application of SCADA in Biomedical Engineering. (2 marks)
- c) Define the term AI. (2 marks)
- d) Explain the importance of AI in biomedical engineering. (4 marks)
- e) Describe the concept of Fuzzy logic as applied in computing. (4 marks)
- f) Explain the concept of machine learning. (2 marks)

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**NATIONAL DIPLOMA**

**IN**

**BIOMEDICAL ENGINEERING**

**MODULE: Biomedical Engineering Mathematics      PAPER NO: 654/23/M01**

**DURATION: 3 Hours**

**JUNE 2026 EXAMINATION**

**REQUIREMENTS**

1. Non-programmable Scientific Calculator.
2. Graph paper.

**INSTRUCTIONS TO CANDIDATES**

1. Question paper contains six (6) questions.
2. Answer five (5) questions only.
3. Each question carries twenty (20) marks.

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*This paper consists of 4 printed pages.*

QUESTION 1

- a) Express the following algebraic expression as a sum of its partial fractions  
$$\frac{x^2-12x+10}{(x+3)(x-1)^2}$$
 (10 marks)

- b) Use De Moivre's theorem to find the value of:

$$(\sqrt{3} + i)^6$$

Express your final answer in the form  $a + bi$  (10 marks)

QUESTION 2

- a) Given the matrices:

$$A = \begin{pmatrix} 2 & -1 \\ 3 & 4 \end{pmatrix} \text{ and } D = \begin{pmatrix} 1 & 0 & 2 \\ -1 & 3 & 5 \end{pmatrix}$$

Evaluate the matrix product  $AB$  and explain why  $BA$  cannot be performed. (8 marks)

- b) Given the matrix

$$A = \begin{pmatrix} 3 & -2 & 1 \\ 1 & 4 & 5 \\ 2 & 1 & 3 \end{pmatrix}$$

Find the determinant of  $A$ . (6 marks)

- c) Find the inverse of the following  $2 \times 2$  matrix.

$$C = \begin{pmatrix} 4 & 7 \\ 2 & 6 \end{pmatrix}$$

(6 marks)

QUESTION 3

- a) Find the Taylor series expansion of the function:

$$F(x) = \ln(x) \text{ about } x = 1$$

Up to and including the term in  $(x - 1)^3$  (8 marks)

- b) The concentration of a drug in patient's bloodstream decreases exponentially over time. The initial concentration is 100mg/L after five (5) hours. The concentration has fallen to 50mg/L.

i) Find the decay rate constant  $k$ . (6 marks)

ii) What will the concentration be after twelve (12) hours. (6 marks)

QUESTION 4

- a) Find the derivative of the following function using logarithmic differentiation.  
 $y = x^{x^2}$  (8 marks)

- b) Solve the following homogenous first order differential equation.  
$$\frac{dy}{dx} = \frac{x^2 + y^2}{2xy}$$

Given that  $y(1) = 1$  (12 marks)

QUESTION 5

- a) Evaluate the following indefinite integral using the method of algebraic substitution.  
 $\int x^2(x^3 + 1)^4 dx$  (8 marks)

- b) Use Simpson's rule with  $n = 4$  to approximate the area under the curve of;  
 $F(x) = \sin(x^2)$

From  $x = 0$  to  $x = 2$  (12 marks)

QUESTION 6

- a) Find the Laplace transform of the function;  $F(t) = t^2 + S$ . (8 marks)
- b) A biomedical sensor records the heart rate (in beats per minute) of eight (8) patients in a study.  
72,85,78,92,85,75,88,85
- i) Calculate standard deviation of this dataset. (8 marks)
- ii) Construct a frequency histogram for this data, using intervals of 5 beats per minute (e.g 70-74, 75-79 etc) (4 marks)

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**HIGHER EDUCATION EXAMINATIONS COUNCIL  
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**NATIONAL DIPLOMA**

**IN**

**BIOMEDICAL ENGINEERING**

**MODULE: Biomedical Engineering Embedded Systems 1 PAPER NO: 654/23/M02**

**DURATION: 3 Hours**

**JUNE 2026 EXAMINATION**

**REQUIREMENTS**

**INSTRUCTIONS TO CANDIDATE**

- 1) Examination consists of six (6) questions
- 2) Each question carries twenty (20) marks.
- 3) Answer any five (5) questions.
- 4) Begin each question on a new page.

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*This paper consists of 3 printed pages.*

QUESTION 1

- a) List four (4) different types of embedded systems (4 marks)
- b) Define the term 'embedded system' and describe its basic functional components using a labelled block diagram. (6 marks)
- c) Explain the major differences between a microcontroller and a microprocessor. (6 marks)
- d) A hospital wants to design a patient bedside monitoring system. Classify this system according to the embedded systems categories you know and state two (2) reasons for your classification. (4 marks)

QUESTION 2

- a) Define the term 'model' in the context of embedded systems design requirements. (2 marks)
- b) Describe the two (2) types of hierarchies used in embedded systems modelling. (2 marks)
- c) A biomedical engineer is modelling a temperature-controlled incubator system. Describe how you would model the thermal behaviour of this system, identifying the key parameters and variables involved. (8 marks)
- d) Explain the factors that must be considered when establishing the requirements of an embedded system for a blood glucose monitoring device. Apply this to specify at least three (3) functional requirements. (6 marks)

QUESTION 3

- a) List five (5) internal elements of the 8088 microprocessor and state the function of each. (5 marks)
- b) Distinguish between the Von Neumann and Harvard architectures. (6 marks)
- c) Compare the CISC and RISC architectures (6 marks)
- d) Explain which architecture, between RISC and CISC that you would recommend for a real time biomedical embedded system. (3 marks)

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QUESTION 4

- a) State the difference between RAM and ROM and identify the specific type used to store a permanent program in an embedded medical device. (3 marks)
- b) Describe any three (3) addressing modes available in the 8088 microprocessors. (3 marks)
- c) Explain the concept of full address decoding versus partial address decoding (4 marks)
- d) A microprocessor has a 16-bit address bus. Describe how you would use full decoding to map a 2KB ROM chip starting at address 0x8000. (4 marks)
- e) Explain the difference between immediate and register addressing modes, including how each is used in a data movement operation. (6 marks)

QUESTION 5

- a) Name four (4) types of sensors used in biomedical engineering and state the physical quantity each measures. (4 marks)
- b) Describe the operating principle of an ECG sensor and explain how its output signal is used in patient monitoring. (6 marks)
- c) A technician is designing an embedded system to monitor a patient's blood oxygen level ( $SpO_2$ ) using a pulse oximeter sensor. Describe the signal conditioning steps that must be applied to the raw sensor output before it can be digitised by the microcontrollers ADC. (10 marks)

QUESTION 6

- a) Define the term 'actuator' (2 marks)
- b) Distinguish between electrical and non electrical transducers. (2 marks)
- c) Explain the principle of operation of a pressure sensor and describe how it could be used to monitor blood pressure in an intensive care unit (ICU). (8 marks)
- d) A biomedical engineer needs to drive a solenoid valve from a 3.3V microcontroller output. Using your knowledge of interfacing, describe the circuit you would use and explain why direct connection is not possible. (8 marks)

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**HIGHER EDUCATION EXAMINATIONS COUNCIL  
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**NATIONAL DIPLOMA**

**IN**

**BIOMEDICAL ENGINEERING**

**MODULE: Monitoring and Life Support Equipment PAPER NO: 654/23/M09**

**DURATION: 3 Hours**

**JUNE 2026 EXAMINATION**

**REQUIREMENTS**

**INSTRUCTIONS TO CANDIDATE**

**Answer any five (5) questions.**

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*This paper consists of 3 printed pages.*

QUESTION 1

- (a) Describe the basic principle of operation of a haemodialysis machine (10 marks)
- (b) Describe any two special safety precautions associated with the wet environment of a dialysis machine. (6 marks)
- (c) List four tasks that should be included in a weekly maintenance schedule for a dialysis machine. (4 marks)

QUESTION 2

- (a) Explain the basic principle of operation of an artificial ventilator. (8 marks)
- (b) Describe the function of the "Positive End Expiratory Pressure" (PEEP) settling on a ventilator. (6 marks)
- (c) Explain any three (3) common parameters that a ventilator can measure. (6 marks)

QUESTION 3

- (a) Explain the term "gas blending" in the context of an anaesthesia machine. (4 marks)
- (b) Describe the function of a vaporiser in an anaesthesia machine. (6 marks)
- (c) Draw and label a simple diagram of a breathing circuit for an anaesthesia machine. (10 marks)

QUESTION 4

- (a) State the two (2) main modes of operation of a DC defibrillator. (4 marks)
- (b) Explain the difference between a monophasic and a biphasic defibrillator waveform. (10 marks)
- (c) Briefly describe the 3 general steps involved in testing a defibrillator waveform. (6 marks)

QUESTION 5

- (a) State and explain any four physiological parameters that are commonly monitored in a patient monitor. (8 marks)
- (b) Describe the function of the alarm system on a patient monitor. (6 marks)
- (c) Explain why it is important to use a specific type of electrode e.g. (Ag/AgCl) for ECG monitoring. (6 marks)

QUESTION 6

- (a) A patient is on a ventilator. The “high airway pressure” alarm is sounding. Explain one possible cause for this alarm. (6 marks)
- (b) A dialysis machine is not achieving the correct flow rate. Explain possible causes and corrective measures to address it. (6 marks)
- (c) Before using a defibrillator on a patient, explain why it is crucial to visually check the patient and ensure “clear” before delivering shock. (8 marks)

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**NATIONAL DIPLOMA**

**IN**

**BIOMEDICAL ENGINEERING**

**MODULE: Biomedical Engineering Electronics PAPER NO: 654/23/M04**

**DURATION: 3 Hours**

**NOVEMBER/DECEMBER 2025 EXAMINATION**

**REQUIREMENTS**

**Non programmable calculator.**

**INSTRUCTIONS TO CANDIDATE**

- 1. Answer any five (5) questions.**
- 2. Do not write anything on the questions paper.**
- 3. Do not write your name on either the question paper or answer booklet.**

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*This paper consists of 3 printed pages.*

PAPER NO: 654/23/M04 – BIOMEDICAL ENGINEERING ELECTRONICS

QUESTION 1

- (a) Explain the effects of positive feedback on an amplifier circuit. (4 marks)
- (b) Discuss the Barkhausen criterion for sustained oscillators. (5 marks)
- (c) (i) Design a Wein bridge oscillator circuit. (5 marks)  
(ii) Derive its frequency of oscillations and open loop gain. (6 marks)

QUESTION 2

- (a) Explain the principle of operation of the following
  - (i) Hartley oscillator (5 marks)
  - (ii) Colpitts oscillator (5 marks)
- (b) (i) Explain the operation of a monostable multivibrator. (5 marks)  
(ii) Describe how the pulse width of the monostable multivibrator is determined. (5 marks)

QUESTION 3

- (a) Define the following terms as applied to logic gates.
  - (i) TTL (3 marks)
  - (ii) CMOS (3 marks)
- (b) Explain the concept of a shift register and its use on serial to parallel data shifting. (4 marks)
- (c) Explain the principle of operation of a ripple counter. (5 marks)
- (d) Describe the concept of direct coupling in amplifier stages. (5 marks)

QUESTION 4

- (a) Describe the following codes used in digital techniques, using examples
- (i) BCD (3 marks)
  - (ii) Gray code (3 marks)
- (b) State and apply De Morgan's theorem to simplify the expression  $\overline{A.B + \overline{C}}$  (8 marks)
- (c) Design a half adder circuit using logic gates and produce its truth table. (6 marks)

QUESTION 5

- (a) Describe the process of Amplitude Modulation. (4 marks)
- (b) Show that an AM modulated wave has 3 components:
- a carrier and 2 sidebands. (6 marks)
- (c) Explain the principle of operation of a class B amplifier. (6 marks)
- (d) Calculate the maximum theoretical efficiency of a class B amplifier. (4 marks)

QUESTION 6

- (a) Describe the operation of a D-type flip-flop and explain its main application. (6 marks)
- (b) Explain the building blocks of a switched mode power supply and identify its advantages over a linear power supply. (8 marks)
- (c) Explain the following terms as used in signal conversion
- (i) Resolution (3 marks)
  - (ii) Linearity (3 marks)

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**ZIMBABWE**

**MINISTRY OF HIGHER AND TERTIARY EDUCATION,  
INNOVATION, SCIENCE AND TECHNOLOGY DEVELOPMENT**

**HIGHER EDUCATION EXAMINATIONS COUNCIL  
(HEXCO)**

**NATIONAL DIPLOMA**

**IN**

**BIOMEDICAL ENGINEERING**

**MODULE: Medical Physics**

**PAPER NO: 654/23/M03**

**DURATION: 3 Hours**

**NOVEMBER/DECEMBER 2025 EXAMINATION**

**REQUIREMENTS**

**INSTRUCTIONS TO CANDIDATE**

1. Question paper contains 6 questions.
2. Each question carries 20 marks.
3. Candidates instructed to answer five (5) questions only.
4. Do not write your name on any examination materials and do not write anything on within the question paper.

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*This paper consists of 3 printed pages.*

PAPER NO: 654/23/M03- MEDICAL PHYSICS

QUESTION 1

- a) Differentiate between Bremsstrahlung and characteristic X-rays based on their production mechanisms and energy spectra. (6 marks)
- b) A beam of X-rays with an initial intensity of  $I_0$  passes through a material. If the half value thickness (HVT) of the material is 5cm, calculate the thickness required to attenuate the beam to 12.5% of its initial intensity. (6 marks)
- c) Explain the three (3) primary interactions of radiation with matter: photoelectric effect, Compton scattering and pair production. For each interaction, describe the energy dependency and the typical energy range at which it is most dominant. (8 marks)

QUESTION 2

- a) Define the term image quality in the context of radiological imaging, list and briefly explain three (3) factors that affect image quality. (8 marks)
- b) Explain the processes of image registration and image segmentation. Provide a practical example of where these techniques would be used in medical imaging. (7 marks)
- c) Describe the concept of optimization in radiological imaging and its importance in balancing image quality with patient safety. (5 marks)

QUESTION 3

- a) Define the following radiological quantities and specify their standard units.
- i) Absorbed Dose (4 marks)
  - ii) Equivalent Dose (4 marks)
  - iii) Effective Dose (4 marks)
- b) A Geiger-Müller counter is used to measure radiation. Explain the fundamental principle of its operation. (8 marks)

QUESTION 4

- a) Explain the fundamental principles behind Magnetic resonance Imaging (MRI), focusing on the role of strong magnetic fields, radio frequency pulses and proton precession. (8 marks)
- b) Discuss the difference between a dose calibrator and a well counter in the context of nuclear medicine instrumentation. (6 marks)
- c) Describe the basic physics of ultrasound imaging, explaining how it forms an image without using ionising radiation. Include a discussion of the role of acoustic properties of biological tissues. (6 marks)

QUESTION 5

- a) Describe the general workflow in a radiotherapy department, from a patient's initial consultation to the final treatment. Highlight the key roles of physics in each step. (8 marks)
- b) Explain the purpose and key features of a high energy radiotherapy generator. How does it differ from a diagnostic X-ray tube. (7 marks)
- c) Discuss the importance of safety culture in radiotherapy environment, and provide two specific examples of safety measures that should be in place. (5 marks)

QUESTION 6

- a) Explain the ALARA principle in radiation protection and how it is applied in medical practice. (6 marks)
- b) Differentiate between occupational exposure and public exposure, and explain the rationale for having different annual dose limits for each. (8 marks)
- c) Outline the basic principles of radiation shielding when designing a radiation shielding barrier. (6 marks)

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**NATIONAL DIPLOMA**

**IN**

**BIOMEDICAL ENGINEERING**

**MODULE: Biomedical Engineering Electrical  
Circuits**

**PAPER NO: 654/23/M05**

**DURATION: 3 Hours**

**NOVEMBER/ DECEMBER 2025 EXAMINATION**

**REQUIREMENTS**

**Non-programmable Calculator**

**INSTRUCTIONS TO CANDIDATES**

1. Question paper consist of six (6) questions.
2. Answer any five (5) questions.
3. Do not write your name on the question paper or answer booklet
4. Do not write anything on the question paper.

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*This paper consists of 4 printed pages.*

*This paper consists of 3 printed pages.*

QUESTION 1

- a) Define the following terms:
- i) Resistance (2 marks)
  - ii) Reactance (2 marks)
  - iii) Impedance (2 marks)
  - iv) Admittance (2 marks)
  - v) Resonance (2 marks)
- b) Define the following components of a complex wave:
- i) Constant term (2 marks)
  - ii) Fundamental (2 marks)
  - iii) Odd and even harmonics (2 marks)
- c) State the meaning of each term in the expression  $i = A + B \sin(\omega t + \phi) + C \sin(2\omega t + \phi) + D \sin(3\omega t + \phi)$  (4 marks)

QUESTION 2

- a) Explain the importance of reliability with respect to biomedical equipment. (4 marks)
- b) Sketch and label the graph of the failure rate versus time, and explain the shape of the graph in terms of early, constant and wear-out failure rate periods. (6 marks)
- c) Describe losses in capacitors where dielectrics and leakage capacitance are concerned. (4 marks)
- d) Derive an expression for the force between two parallel plates. (6 marks)

QUESTION 3

- a) Define and explain the following:
- i) Passive networks (3 marks)
  - ii) Insertion loss (3 marks)

- b) A filter is required to pass all frequencies above 25kHz and have a nominal impedance of  $600\Omega$ . Design the following to meet the requirement:
- i) A high pass T-section filter. (6 marks)
  - ii) A high pass H-section filter. (6 marks)
- c) State Thevenin's theorem. (2 marks)

QUESTION 4

- a) Define the following terms:
- i) Magnetic field intensity (3 marks)
  - ii) Hysteresis curve (3 marks)
- b) A silicon iron ring is wound with 800 turns, the ring having a mean diameter of 120mm and a cross-sectional area of  $400\text{mm}^2$ . If, when carrying a current of 0.5A, the relative permeability is found to be 3000. Calculate:
- i) The self-inductance of the coil (7 marks)
  - ii) The induced emf if the current is reduced to zero in 80ms. (3 marks)
- c) State four (4) ways of minimising losses in a conductor. (4 marks)

QUESTION 5

- a) A conductor 300mm long moves at a uniform speed of  $4\text{ms}^{-1}$  at right angle to a uniform magnetic field of flux density  $1.25\text{ T}$ . Determine the current flowing in the conductor when:
- i) Its ends are open-circuited (2 marks)
  - ii) Its ends are connected to a load of  $20\Omega$  resistor. (4 marks)
- b) Define a two (2) port network. (2 marks)
- c) Define the following for a two (2) port network in terms of input and output conditions.
- i) 2-parameters (2 marks)
  - ii) y-parameters (2 marks)

- d) State the advantages of active filters over Passive filters. (4 marks)
- e) Describe the operation of the following:
- i) Basic solenoid (2 marks)
  - ii) Relay (2 marks)

QUESTION 6

- a) Define the following terms:
- i) Permittivity of free space (2 marks)
  - ii) Electric flux (2 marks)
  - iii) Relative permittivity (2 marks)
- b) Explain the relation between failure rate and MTBF. (5 marks)
- c) Discuss the critical role of electric circuit principles in the design, maintenance, repair and decommissioning of medical diagnostic equipment in Zimbabwean hospitals. (Use a specific medical equipment as an example.) (5 marks)

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