GATE Biomedical Engineering

Sample Paper – 10

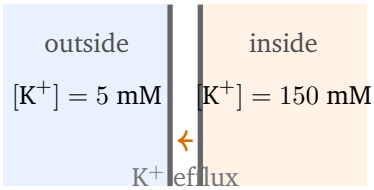
Duration: 128 Minutes **Maximum Marks: 72**

Instructions

- This paper contains **46 questions** covering the core **Biomedical Engineering** subject of the GATE paper conducted by the IITs and IISc (General Aptitude and Engineering Mathematics are provided as separate papers).
- **Q1–Q20 carry 1 mark each** and **Q21–Q46 carry 2 marks each**, for a total of **72 marks**.
- Each question carries **negative marking of one-third of its allotted marks**: a wrong 1-mark question costs **0.33** and a wrong 2-mark question costs **0.67**. Unattempted questions carry no penalty.
- Every question here is a single-correct **MCQ**. The real GATE paper also has Multiple Select (MSQ) and Numerical Answer Type (NAT) questions, and **those carry no negative marking**.
- Attempt this paper in one timed sitting of about **128 minutes**, the share this core subject earns at GATE's overall pace of 180 minutes for 65 questions. Use standard physiological values (resting membrane potential ≈ -70 mV, speed of sound in soft tissue ≈ 1540 m/s) unless stated otherwise.

Human Anatomy and Physiology

Q1. A cell membrane separates the potassium concentrations shown below. Using the Nernst relation $E_K = 61 \log_{10} \dfrac{[\mathrm{K}^+]_{\text{out}}}{[\mathrm{K}^+]_{\text{in}}}$ mV with $[\mathrm{K}^+]_{\text{out}} = 5$ mM and $[\mathrm{K}^+]_{\text{in}} = 150$ mM, the potassium equilibrium (Nernst) potential is nearest to: **[1 mark]**



(A) $+90$ mV

(B) -61 mV

(C) -90 mV

(D) -30 mV

Q2. The sodium–potassium pump (Na^+/K^+-ATPase) maintains the resting ionic gradients of an excitable cell. Per molecule of ATP hydrolysed, this pump transports: **[1 mark]**

(A) 2 Na^+ out of the cell and 3 K^+ into the cell

(B) 3 Na^+ into the cell and 2 K^+ out of the cell

(C) 3 Na^+ out of the cell and 2 K^+ into the cell

(D) 1 Na^+ out of the cell and 1 K^+ into the cell

Q3. Glucose enters a cell by moving down its concentration gradient through a specific carrier (transporter) protein, with no expenditure of metabolic energy. This mode of membrane transport is: **[1 mark]**

(A) facilitated diffusion

(B) primary active transport

(C) secondary active transport

(D) simple diffusion through the lipid bilayer

Q4. The normal pH of arterial blood in a healthy human, tightly regulated by buffer systems, is closest to: **[1 mark]**

(A) 7.0

(B) 6.8

(C) 7.4

(D) 8.0

Q5. The neurotransmitter released at the neuromuscular junction to trigger contraction of a skeletal muscle fibre is: **[1 mark]**

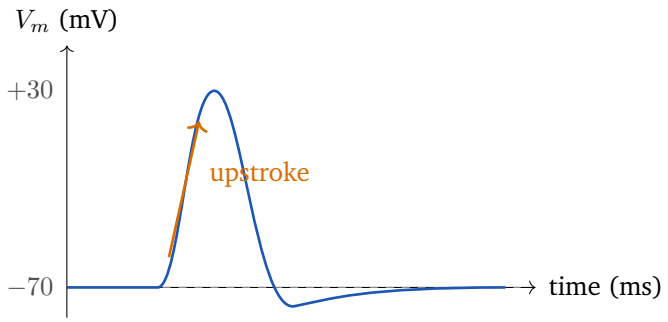
(A) acetylcholine

(B) dopamine

(C) gamma-aminobutyric acid (GABA)

(D) serotonin

Q6. The rising (depolarising) phase of a neuronal action potential, sketched below, is produced when voltage-gated channels open and the membrane potential is driven toward the equilibrium potential of one particular ion. That ion is: **[1 mark]**



(A) K^+ (potassium)

(B) Cl^- (chloride)

(C) Na^+ (sodium)

(D) Ca^{2+} (calcium)

Electric Circuits, Signals and Systems

Q7. The z-transform of the discrete-time unit step sequence $u[n]$ (which is 1 for $n \geq 0$ and 0 otherwise) is: **[1 mark]**

(A) 1

(B) $\dfrac{1}{1-z}$

(C) $\dfrac{z}{z-1}, \quad |z| > 1$

(D) $\dfrac{z}{z+1}$

Q8. A causal discrete-time LTI system is described by a rational transfer function $H(z)$. It is bounded-input bounded-output (BIBO) stable if and only if all of its poles lie: **[1 mark]**

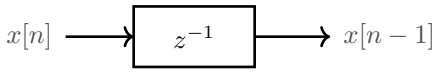
(A) outside the unit circle

(B) on the unit circle

(C) in the left half of the z-plane

(D) inside the unit circle ($|z| < 1$)

Q9. In the discrete-time block diagram shown, the element delays its input by exactly one sample, giving $y[n] = x[n-1]$. In the z-domain this operation multiplies $X(z)$ by: **[1 mark]**



(A) z

(B) z^2

(C) $-z$

(D) z^{-1}

Q10. Two finite-length discrete sequences are $x[n] = \{1, 2\}$ and $h[n] = \{1, 3\}$ (both starting at $n = 0$). Their linear convolution $y[n] = x[n] * h[n]$ is: **[1 mark]**

(A) $\{1, 5, 6\}$

(B) $\{1, 3, 6\}$

(C) $\{1, 2, 6\}$

(D) $\{1, 6, 5\}$

Q11. A discrete-time system obeys the difference equation $y[n] = x[n] - x[n-1]$. In the frequency domain this first-difference operation behaves as a: **[1 mark]**

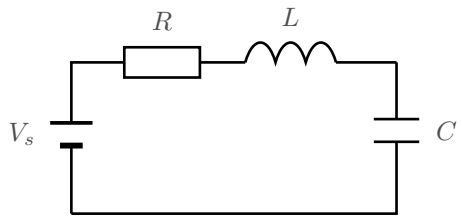
(A) first-difference (high-pass) filter that emphasises rapid changes

(B) running accumulator (low-pass) filter

(C) pure one-sample delay

(D) all-pass filter

Q12. The series RLC circuit shown has $L = 1$ mH and $C = 1\ \mu$F. Its undamped resonant frequency $f_0 = \dfrac{1}{2\pi\sqrt{LC}}$ is nearest to: **[1 mark]**



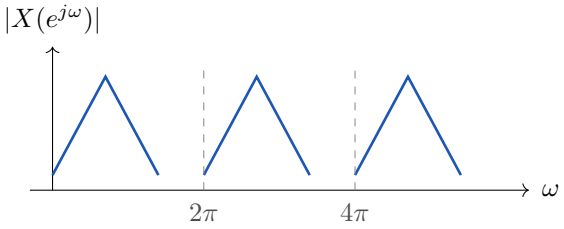
(A) 500 Hz

(B) 50 kHz

(C) 1 kHz

(D) 5 kHz

Q13. The discrete-time Fourier transform (DTFT) $X(e^{j\omega})$ of any sequence, sketched below as a function of the digital frequency ω, is a periodic function of ω with period: **[1 mark]**



(A) 2π

(B) π

(C) 4π

(D) 1

Analog and Digital Electronics

Q14. Two amplifier stages are cascaded (connected in series). The first stage has a voltage gain of -10 and the second stage a voltage gain of -5. The overall voltage gain of the two-stage amplifier is: **[1 mark]**

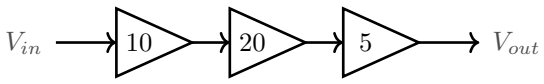
(A) -50

(B) -15

(C) $+50$

(D) $+15$

Q15. The three-stage cascaded amplifier shown has individual voltage gains of 10, 20 and 5. Its overall voltage gain expressed in decibels, $A_{\text{dB}} = 20\log_{10}\left(\dfrac{V_{out}}{V_{in}}\right)$, is: **[1 mark]**



(A) 35 dB

(B) 60 dB

(C) 100 dB

(D) 30 dB

Q16. In a multistage RC-coupled amplifier, the coupling capacitor connected between the output of one stage and the input of the next stage serves to: **[1 mark]**

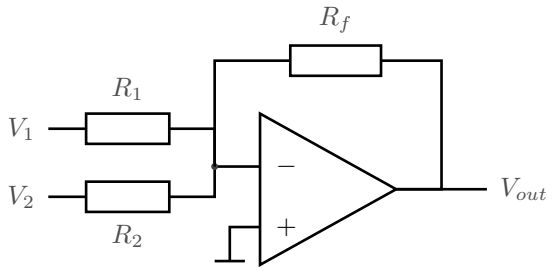
(A) increase the DC bias current of the next stage

(B) provide DC negative feedback

(C) block the DC bias level while passing the AC signal between stages

(D) bypass the AC signal to ground

Q17. For the ideal inverting summing amplifier shown, the input resistors and the feedback resistor are all $R_f = R_1 = R_2 = 10$ kΩ, so that $V_{out} = -(V_1 + V_2)$. With $V_1 = 1$ V and $V_2 = 2$ V, the output voltage is: **[1 mark]**



(A) -3 V

(B) $+3$ V

(C) -1.5 V

(D) -30 V

Q18. A 4-to-1 digital multiplexer routes one of four data inputs to a single output. The number of select (control) lines it requires is: **[1 mark]**

(A) 4

(B) 1

(C) 3

(D) 2

Q19. The 8-bit two's-complement representation of the decimal number -5 is: **[1 mark]**

(A) 1111 1011

(B) 0000 0101

(C) 1111 1010

(D) 1000 0101

Sensors, Bioinstrumentation and Measurements

Q20. A Wheatstone bridge has all four arms initially equal to R, and one arm changes by a small amount ΔR. For $\Delta R \ll R$, the bridge output (unbalance) voltage is, to first order, proportional to: [1 mark]

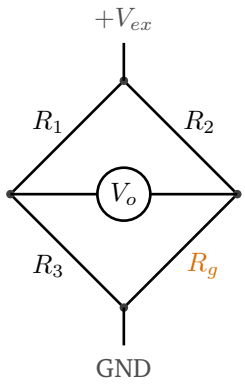
(A) $\left(\dfrac{\Delta R}{R}\right)^2$

(B) $\dfrac{\Delta R}{R}$

(C) $\dfrac{R}{\Delta R}$

(D) a constant independent of ΔR

Q21. The quarter-bridge circuit shown carries a single active metal-foil strain gauge of gauge factor 2.0 in one arm, excited by $V_{ex} = 6$ V. When the specimen is strained by $2000\ \mu\varepsilon$ ($\varepsilon = 2\times10^{-3}$), the output is $V_o = \dfrac{V_{ex}}{4}(\text{GF}\cdot\varepsilon)$. The output voltage is: [2 marks]



(A) 3 mV

(B) 12 mV

(C) 6 mV

(D) 1.5 mV

Q22. A classic three-op-amp instrumentation amplifier has its differential gain set by a single external resistor R_G according to $A_d = 1 + \dfrac{2R}{R_G}$. With the internal resistors $R = 25\ \text{k}\Omega$ and $R_G = 1\ \text{k}\Omega$, the differential gain is: [2 marks]

(A) 50

(B) 51

(C) 26

(D) 101

Q23. A bridge (instrumentation) amplifier has a differential-mode gain of $A_d = 500$ and a common-mode rejection ratio of 100 dB. Since CMRR $= A_d/A_c$, the common-mode gain A_c of the amplifier is: **[2 marks]**

(A) 0.005

(B) 0.05

(C) 0.5

(D) 5

Q24. A piezoelectric transducer generates a charge only while the applied mechanical stress is changing. It is therefore best suited to measuring: **[2 marks]**

(A) a steady (DC) displacement held for minutes

(B) a dynamic (rapidly varying) pressure or force, such as a heart sound

(C) a constant temperature

(D) a fixed DC voltage

Q25. Silver–silver chloride (Ag/AgCl) electrodes are the standard choice for surface biopotential recording (ECG, EEG, EMG) chiefly because such an electrode: **[2 marks]**

(A) has an extremely high contact impedance

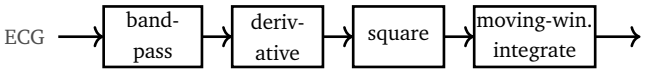
(B) is a strongly polarisable electrode that blocks DC

(C) is nearly non-polarisable, giving a stable half-cell potential with low motion artefact

(D) generates its own EMF proportional to skin temperature

Biomedical Signal Processing

Q26. The Pan–Tompkins algorithm for real-time QRS detection processes the ECG through the pipeline sketched below. The correct order of the processing stages is: [2 marks]



(A) band-pass filter $\rightarrow$ derivative $\rightarrow$ squaring $\rightarrow$ moving-window integration

(B) squaring $\rightarrow$ derivative $\rightarrow$ band-pass filter $\rightarrow$ integration

(C) integration $\rightarrow$ squaring $\rightarrow$ derivative $\rightarrow$ band-pass filter

(D) derivative $\rightarrow$ band-pass filter $\rightarrow$ integration $\rightarrow$ squaring

Q27. In the Pan–Tompkins QRS detector the squaring stage is applied to the differentiated signal mainly to: [2 marks]

(A) make every sample positive and non-linearly emphasise the large slopes of the QRS

(B) remove baseline wander

(C) reduce the sampling rate of the record

(D) linearly attenuate all samples equally

Q28. In a recorded ECG, successive R-peaks (detected by a QRS algorithm) are separated by an R–R interval of 0.8 s. The corresponding instantaneous heart rate is: [2 marks]

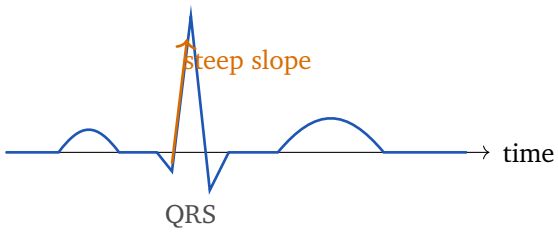
(A) 60 beats/min

(B) 75 beats/min

(C) 80 beats/min

(D) 48 beats/min

Q29. The ECG segment shown is passed through the derivative (differentiation) stage of a QRS detector. This stage responds most strongly to, and therefore extracts, the: [2 marks]



(A) slope (rate of change) of the QRS complex

(B) area under the P wave

(C) DC baseline offset

(D) noise floor only

Q30. The recommended diagnostic-mode bandwidth for recording a standard clinical (12-lead) ECG is approximately: **[2 marks]**

(A) 0.5 Hz to 5 Hz

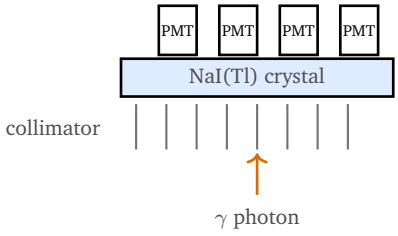
(B) 100 Hz to 1 kHz

(C) 1 Hz to 10 Hz

(D) 0.05 Hz to 100 Hz

Medical Imaging Systems

Q31. In the gamma (Anger) camera sketched below, the component that converts each incident gamma photon into a flash of visible light (a scintillation) is the: **[2 marks]**



(A) photomultiplier tube

(B) lead collimator

(C) pulse-height analyser

(D) sodium iodide NaI(Tl) scintillation crystal

Q32. In a gamma camera, the lead collimator placed in front of the scintillation crystal serves to: [2 marks]

(A) convert the scintillation light into electrical pulses

(B) accept only gamma photons travelling along defined directions, thereby forming the image and setting spatial resolution

(C) amplify the scintillation light before it reaches the crystal

(D) filter out ambient visible light

Q33. The radionuclide most widely used in SPECT imaging, emitting a 140 keV gamma ray with a physical half-life of about 6 hours, is: [2 marks]

(A) fluorine-18

(B) iodine-131

(C) technetium-99m

(D) thallium-201

Q34. Which imaging modality reconstructs three-dimensional tomographic slices from many planar gamma-camera projections acquired as the detector head rotates around the patient? [2 marks]

(A) planar chest X-ray

(B) A-mode ultrasound

(C) fluoroscopy

(D) single-photon emission computed tomography (SPECT)

Q35. In the Anger gamma camera, the array of photomultiplier tubes mounted behind the scintillation crystal is used to: [2 marks]

(A) sense and amplify the scintillation light, providing the position (X, Y) and energy signals for each event

(B) collimate the incoming gamma rays

(C) generate the gamma photons that are emitted

(D) cool the scintillation crystal

Biomechanics and Biomaterials

Q36. An orthopaedic implant subjected to repeated (cyclic) loading during walking can eventually break at a stress well below its ultimate tensile strength. This progressive mode of failure is called: **[2 marks]**

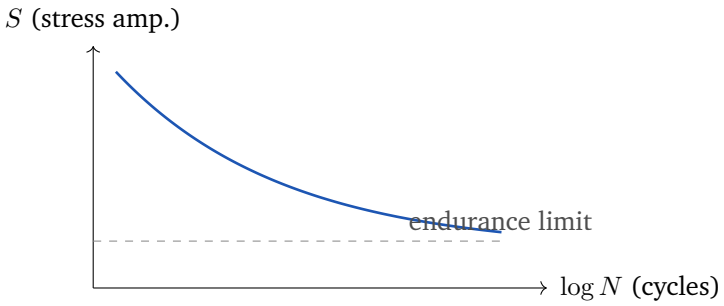
(A) creep

(B) fatigue

(C) yielding

(D) corrosion

Q37. The curve shown, which plots the cyclic stress amplitude S against the number of loading cycles to failure N for an implant alloy, is known as the: **[2 marks]**



(A) stress–strain curve

(B) creep curve

(C) hysteresis loop

(D) S–N (Wöhler) curve

Q38. For a titanium implant alloy, the maximum cyclic stress amplitude below which the material can withstand essentially an unlimited number of loading cycles without fatigue failure is called the: **[2 marks]**

(A) ultimate tensile strength

(B) endurance (fatigue) limit

(C) yield strength

(D) proportional limit

Q39. In a metal-on-polyethylene total hip replacement, the mechanism that dominates the generation of wear debris at the articulating surface over many years of use is: **[2 marks]**

(A) fatigue of the bone cement alone

(B) adhesive and abrasive wear of the polyethylene bearing surface

(C) galvanic corrosion of the ceramic head

(D) thermal expansion mismatch

Q40. The polymer most widely used as the low-friction bearing liner (acetabular cup insert) in total hip and knee replacements is: **[2 marks]**

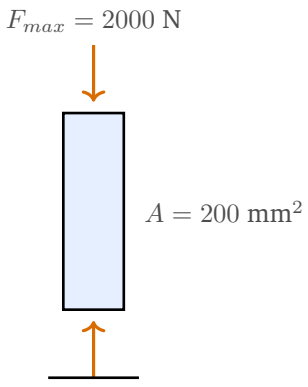
(A) poly(methyl methacrylate) (PMMA) bone cement

(B) polytetrafluoroethylene (PTFE)

(C) medical-grade silicone rubber

(D) ultra-high-molecular-weight polyethylene (UHMWPE)

Q41. The hip-implant stem shown has a uniform cross-sectional area of 200 mm^2 and carries a cyclic axial load that swings between 0 and 2000 N during walking. The maximum axial (normal) stress reached in each loading cycle is: **[2 marks]**



(A) 5 MPa

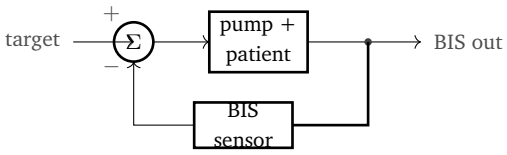
(B) 10 MPa

(C) 20 MPa

(D) 100 MPa

Control Systems and Medical Instrumentation

Q42. The target-controlled anaesthesia system shown continuously measures the patient's depth of anaesthesia (a BIS-type index) and automatically adjusts the anaesthetic infusion rate to hold it at the set target. This arrangement is an example of: **[2 marks]**



(A) an open-loop system

(B) a purely feedforward system

(C) a negative-feedback (closed-loop) control system

(D) an uncontrolled (manual) system

Q43. A syringe infusion pump must deliver an anaesthetic drug at a set rate of 6 mL per hour. Expressed per minute, this flow rate is: **[2 marks]**

(A) 1 mL/min

(B) 0.1 mL/min

(C) 0.6 mL/min

(D) 60 mL/min

Q44. An intravenously infused drug is eliminated from the body by first-order kinetics, modelled as a single-pole (first-order) system with a time constant of 4 hours. The time taken for the plasma concentration to fall to about 37% of its initial value is: **[2 marks]**

(A) 2 hours

(B) 4 hours

(C) 8 hours

(D) 1 hour

Q45. A closed-loop anaesthesia controller is a unity-feedback system whose open-loop DC gain is $K = 99$. For a unit-step change in the target, the steady-state error of a type-0 unity-feedback system is $e_{ss} = \dfrac{1}{1+K}$. This steady-state error is: **[2 marks]**

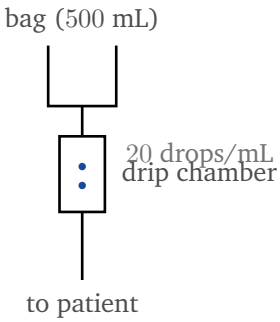
(A) 0.5

(B) 0.99

(C) 0.1

(D) 0.01

Q46. A gravity intravenous (IV) infusion set delivers 20 drops per millilitre through the drip chamber shown. To infuse 500 mL of fluid over 5 hours, the required drip rate is: **[2 marks]**



(A) 20 drops/min

(B) 100 drops/min

(C) 50 drops/min

(D) 33 drops/min

Detailed Solutions

Q1.

Solution

Concept – Nernst (equilibrium) potential of an ion: The Nernst potential is the transmembrane voltage at which the electrical force on an ion exactly balances the diffusive force set by its concentration gradient.

Step 1 – write the relation for potassium: $E_K = 61 \log_{10} \frac{[K^+]_{out}}{[K^+]_{in}}$ mV.

Step 2 – substitute the given concentrations: $E_K = 61 \log_{10} \frac{5}{150}$

Step 3 – simplify the ratio: $\frac{5}{150} = \frac{1}{30}$

Step 4 – evaluate the logarithm: $\log_{10} \frac{1}{30} = -\log_{10} 30 = -1.477$

Step 5 – multiply: $E_K = 61 \times (-1.477)$

$E_K = -90.1$ mV ≈ -90 mV

Why the other options are wrong:

- A, $+90$ mV: has the wrong sign; K^+ is more concentrated inside, so the equilibrium potential is negative.
- B, -61 mV: would result only from a $10:1$ ratio, not $30:1$.
- D, -30 mV: ignores the logarithmic factor.

Final Answer: $E_K \approx -90$ mV $\Rightarrow$ C

Answer: (C) Go Back to Q1

Q2.

Solution

Concept – the Na^+/K^+-ATPase pump stoichiometry: This primary active transporter uses the energy of one ATP to move both ions against their gradients.

Step 1 – recall the direction of pumping: Na^+ is pumped out of the cell (against its inward gradient) and K^+ is pumped into the cell (against its outward gradient).

Step 2 – recall the numbers per ATP: For each ATP hydrolysed, 3 Na^+ leave and 2 K^+ enter.

Step 3 – note the consequence: Because 3 positive charges leave for every 2 that enter, the pump is electrogenic and helps maintain the negative resting potential.

Why the other options are wrong:

- A: reverses the two ion counts.
- B: reverses both directions of transport.
- D: gives a $1{:}1$ ratio, which is not the ATPase stoichiometry.

Final Answer: $3\ Na^+$ out, $2\ K^+$ in $\Rightarrow$ C

Answer: (C) Go Back to Q2

Q3.

Solution

Concept – classes of membrane transport: Transport is classified by whether it needs a carrier and whether it consumes metabolic energy.

Step 1 – note the direction of movement: Glucose moves *down* its concentration gradient (high to low), so no energy input is needed.

Step 2 – note the need for a carrier: Glucose is polar and cannot cross the lipid bilayer freely; it requires a specific transporter protein (e.g. GLUT).

Step 3 – combine the two facts: Passive movement down a gradient *through a carrier* is, by definition, facilitated diffusion.

Why the other options are wrong:

- B and C: active transport moves solutes *against* a gradient and needs energy, directly (primary) or coupled (secondary).
- D: simple diffusion through the bilayer applies to small nonpolar molecules, not to glucose.

Final Answer: facilitated diffusion $\Rightarrow$ A

Answer: (A) Go Back to Q3

Q4.

Solution

Concept – acid–base balance of blood: Arterial blood pH is held within a narrow band by the bicarbonate buffer, respiration and the kidneys.

Step 1 – recall the regulated set-point: Normal arterial blood pH is about 7.35 to 7.45, centred near 7.4.

Step 2 – pick the closest value: Of the choices, 7.4 matches the physiological

set-point.

Why the other options are wrong:

- A, 7.0: is neutral water, and in blood it signals severe acidosis.
- B, 6.8: is incompatible with life.
- D, 8.0: represents extreme alkalosis.

Final Answer: blood pH $\approx 7.4 \Rightarrow$ C

Answer: (C) Go Back to Q4

Q5.

Solution

Concept – neurotransmission at the neuromuscular junction: A specific transmitter carries the signal from the motor neuron to the muscle fibre.

Step 1 – identify the synapse: The motor nerve ending meets the skeletal muscle at the motor end-plate.

Step 2 – name the transmitter released there: Acetylcholine is released, binds nicotinic receptors on the muscle, and triggers an end-plate potential that leads to contraction.

Why the other options are wrong:

- B, dopamine: acts mainly in central pathways, not at the skeletal neuromuscular junction.
- C, GABA: is the chief inhibitory transmitter of the central nervous system.
- D, serotonin: modulates mood, gut and vascular tone, not skeletal end-plates.

Final Answer: acetylcholine $\Rightarrow$ A

Answer: (A) Go Back to Q5

Q6.

Solution

Concept – ionic basis of the action-potential upstroke: During depolarisation the membrane potential is driven toward the Nernst potential of whichever ion channel is open.

Step 1 – identify which channels open first: At threshold, voltage-gated *sodium*

channels open rapidly.

Step 2 – note the sodium gradient: Na^+ is far more concentrated outside the cell, so its equilibrium potential is about $+60$ mV.

Step 3 – conclude the direction of the upstroke: With Na^+ channels open, the membrane potential swings sharply positive toward E_{Na}, producing the rising phase.

Why the other options are wrong:

- A, K^+: its channels dominate during *repolarisation*, driving V_m negative.
- B, Cl^-: contributes to stabilising the resting potential, not the upstroke.
- D, Ca^{2+}: matters in cardiac and synaptic events, not the fast neuronal upstroke.

Final Answer: sodium (Na^+) $\Rightarrow$ C

Answer: (C) Go Back to Q6

Q7.

Solution

Concept – z-transform of a standard sequence: $X(z) = \sum_{n=-\infty}^{\infty} x[n]\, z^{-n}$.

Step 1 – write the sum for the unit step: $U(z) = \sum_{n=0}^{\infty} 1 \cdot z^{-n}$

Step 2 – recognise the geometric series: $U(z) = \sum_{n=0}^{\infty} (z^{-1})^n$, which converges when $|z^{-1}| < 1$, i.e. $|z| > 1$.

Step 3 – sum the geometric series: $U(z) = \dfrac{1}{1 - z^{-1}}$

Step 4 – express with positive powers of z: Multiply numerator and denominator by z: $U(z) = \dfrac{z}{z-1}$, $|z| > 1$.

Why the other options are wrong:

- A, 1: is the transform of the unit impulse $\delta[n]$, not the step.
- B, $\frac{1}{1-z}$: has the wrong power of z and wrong region.
- D, $\frac{z}{z+1}$: is the transform of $(-1)^n u[n]$.

Final Answer: $U(z) = \dfrac{z}{z-1}$, $|z| > 1 \Rightarrow$ C

Answer: (C) Go Back to Q7

Q8.

Solution

Concept – BIBO stability of a discrete-time system: Stability of a causal LTI system is decided by where its poles sit relative to the unit circle in the z-plane.

Step 1 – state the stability criterion: A causal discrete-time system is BIBO stable if and only if its impulse response is absolutely summable, $\sum |h[n]| < \infty$.

Step 2 – translate to pole locations: This condition is equivalent to every pole of $H(z)$ having magnitude less than one, i.e. lying strictly inside the unit circle.

Step 3 – interpret a pole on or outside the circle: A pole on the unit circle gives a marginally stable (non-decaying) term; a pole outside it gives a growing term, so the system is unstable.

Why the other options are wrong:

- A, outside: gives unbounded, growing responses.
- B, on the circle: is only marginally stable, not BIBO stable.
- C, left half-plane: is the *continuous*-time (s-plane) criterion, not the discrete one.

Final Answer: poles inside the unit circle $\Rightarrow$ D

Answer: (D) Go Back to Q8

Q9.

Solution

Concept – time-shift property of the z-transform: Delaying a sequence in time multiplies its transform by a power of z^{-1}.

Step 1 – state the property: If $x[n] \leftrightarrow X(z)$, then $x[n-k] \leftrightarrow z^{-k}X(z)$.

Step 2 – apply a one-sample delay ($k = 1$): $x[n-1] \leftrightarrow z^{-1}X(z)$.

Step 3 – interpret the block: The z^{-1} block is therefore a single unit delay, the basic memory element of any digital filter.

Why the other options are wrong:

- A, z: represents a one-sample *advance*, $x[n+1]$.
- B, z^2: is a two-sample advance.

- C, $-z$: has no standard shift meaning.

Final Answer: multiply by $z^{-1} \Rightarrow$ D

Answer: (D) Go Back to Q9

Q10.

Solution

Concept – linear convolution of two short sequences: $y[n] = \sum_k x[k]\,h[n-k]$; the output length is $2 + 2 - 1 = 3$ samples.

Step 1 – list the samples: $x[0] = 1,\ x[1] = 2$ and $h[0] = 1,\ h[1] = 3$.

Step 2 – compute $y[0]$: $y[0] = x[0]h[0] = 1 \times 1 = 1$

Step 3 – compute $y[1]$: $y[1] = x[0]h[1] + x[1]h[0] = (1 \times 3) + (2 \times 1) = 3 + 2 = 5$

Step 4 – compute $y[2]$: $y[2] = x[1]h[1] = 2 \times 3 = 6$

Step 5 – assemble the result: $y[n] = \{1,\ 5,\ 6\}$

Why the other options are wrong:

- B, C: use an incorrect middle term (the cross-products were dropped).
- D: swaps the last two samples.

Final Answer: $\{1,\ 5,\ 6\} \Rightarrow$ A

Answer: (A) Go Back to Q10

Q11.

Solution

Concept – frequency response of a first-difference system: $y[n] = x[n] - x[n-1]$ has $H(z) = 1 - z^{-1}$.

Step 1 – evaluate the response on the unit circle: $H(e^{j\omega}) = 1 - e^{-j\omega}$.

Step 2 – find the magnitude: $|H(e^{j\omega})| = |1 - e^{-j\omega}| = 2\left|\sin\frac{\omega}{2}\right|$.

Step 3 – read the behaviour at the band edges: At $\omega = 0$ (DC), $|H| = 0$; at $\omega = \pi$ (highest digital frequency), $|H| = 2$.

Step 4 – classify the filter: It blocks DC and passes rapid changes, so it is a first-difference (high-pass) filter that emphasises sharp transitions such as QRS edges.

Why the other options are wrong:

- B, accumulator: is the *inverse* operation and is low-pass.
- C, pure delay: would leave the magnitude flat at 1.
- D, all-pass: also has flat unity magnitude.

Final Answer: first-difference (high-pass) filter $\Rightarrow$ A

Answer: (A) Go Back to Q11

Q12.

Solution

Concept – resonant frequency of a series RLC circuit: $f_0 = \dfrac{1}{2\pi\sqrt{LC}}$.

Step 1 – list the data in base units: $L = 1$ mH $= 10^{-3}$ H, $C = 1\ \mu$F $= 10^{-6}$ F.

Step 2 – form the product LC: $LC = 10^{-3} \times 10^{-6} = 10^{-9}$

Step 3 – take the square root: $\sqrt{LC} = \sqrt{10^{-9}} = 3.16 \times 10^{-5}$ s

Step 4 – multiply by 2π: $2\pi\sqrt{LC} = 6.283 \times 3.16 \times 10^{-5} = 1.986 \times 10^{-4}$

Step 5 – take the reciprocal: $f_0 = \dfrac{1}{1.986 \times 10^{-4}} = 5034$ Hz ≈ 5 kHz

Why the other options are wrong:

- A, 500 Hz and C, 1 kHz: are off by an order of magnitude.
- B, 50 kHz: would need LC a hundred times smaller.

Final Answer: $f_0 \approx 5$ kHz $\Rightarrow$ D

Answer: (D) Go Back to Q12

Q13.

Solution

Concept – periodicity of the DTFT: The DTFT is built from complex exponentials $e^{j\omega n}$, which repeat in ω.

Step 1 – use the periodicity of the exponential: $e^{j(\omega+2\pi)n} = e^{j\omega n}\, e^{j2\pi n} = e^{j\omega n}$, since $e^{j2\pi n} = 1$ for every integer n.

Step 2 – carry this into the transform: Because every term repeats when ω increases by 2π, the whole sum $X(e^{j\omega})$ repeats with period 2π.

Step 3 – confirm from the sketch: The identical spectral shape recurs at $\omega = 0,\ 2\pi,\ 4\pi, \ldots$, exactly a 2π spacing.

Why the other options are wrong:

- B, π: is only the half-period (highest unique frequency), not the full period.
- C, 4π: is two full periods.
- D, 1: has the wrong units (the period is in radians/sample).

Final Answer: period $= 2\pi \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q13

Q14.

Solution

Concept – overall gain of cascaded amplifier stages: When stages are connected in series, their voltage gains multiply.

Step 1 – write the product: $A_{\text{total}} = A_1 \times A_2$

Step 2 – substitute the stage gains: $A_{\text{total}} = (-10) \times (-5)$

Step 3 – multiply, tracking the signs: A negative times a negative is positive, and $10 \times 5 = 50$.

$A_{\text{total}} = +50$

Why the other options are wrong:

- A, -50: keeps a negative sign, but two inversions cancel.
- B and D, ± 15: add the gains instead of multiplying them.

Final Answer: $A_{\text{total}} = +50 \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q14

Q15.

Solution

Concept – overall gain of a multistage amplifier in decibels: The linear gains multiply, so their decibel values add.

Step 1 – find the overall linear gain: $A = 10 \times 20 \times 5$

$A = 1000$

Step 2 – convert to decibels: $A_{\text{dB}} = 20 \log_{10}(1000)$

Step 3 – evaluate the logarithm: $\log_{10}(1000) = 3$

Step 4 – multiply: $A_{\text{dB}} = 20 \times 3 = 60$ dB

Step 5 – cross-check by adding stage decibels: $20\log_{10} 10 = 20$; $20\log_{10} 20 \approx 26$; $20\log_{10} 5 \approx 14$; sum ≈ 60 dB.

Why the other options are wrong:

- A, 35 dB and D, 30 dB: correspond to gains far below 1000.
- C, 100 dB: corresponds to a gain of 10^5, not 10^3.

Final Answer: $A_{\text{dB}} = 60$ dB $\Rightarrow$ B

Answer: (B) Go Back to Q15

Q16.

Solution

Concept – role of the coupling capacitor in an RC-coupled amplifier: A capacitor passes AC but blocks steady DC.

Step 1 – recall each stage has its own DC bias: Every transistor stage sits at a specific DC operating (Q) point that must not be disturbed by the neighbouring stage.

Step 2 – see what must be transferred: Only the AC signal should move from one stage to the next; the DC bias levels must stay isolated.

Step 3 – assign the capacitor's function: The series coupling capacitor blocks the DC level of one stage while letting the AC signal pass, so each stage keeps its own bias.

Why the other options are wrong:

- A: the capacitor blocks DC, it does not carry bias current between stages.
- B: DC feedback is not its purpose; it actually blocks DC.
- D: a *bypass* capacitor to ground is a different component with a different role.

Final Answer: blocks DC, passes AC between stages $\Rightarrow$ C

Answer: (C) Go Back to Q16

Q17.

Solution

Concept – inverting summing amplifier: With a virtual ground at the inverting input, $V_{out} = -\left(\frac{R_f}{R_1}V_1 + \frac{R_f}{R_2}V_2\right)$.

Step 1 – apply the equal-resistor condition: All resistors are 10 kΩ, so $\frac{R_f}{R_1} = \frac{R_f}{R_2} = 1$.

Step 2 – simplify the transfer equation: $V_{out} = -(V_1 + V_2)$

Step 3 – substitute the input voltages: $V_{out} = -(1 + 2)$

Step 4 – add and apply the sign: $V_{out} = -3$ V

Why the other options are wrong:

- B, $+3$ V: drops the inverting sign.
- C, -1.5 V: averages the inputs instead of summing them.
- D, -30 V: uses a gain of 10 per input, which the equal resistors do not give.

Final Answer: $V_{out} = -3$ V $\Rightarrow$ A

Answer: (A) Go Back to Q17

Q18.

Solution

Concept – select lines of a multiplexer: A multiplexer with 2^k data inputs needs k select lines to address them.

Step 1 – count the data inputs: A 4-to-1 MUX has 4 inputs.

Step 2 – solve $2^k = 4$: $2^k = 4 = 2^2$, so $k = 2$.

Step 3 – state the requirement: Two select lines can address the four inputs $(00, 01, 10, 11)$.

Why the other options are wrong:

- A, 4: equals the number of inputs, not the address lines.
- B, 1: would address only 2 inputs.
- C, 3: would address up to 8 inputs.

Final Answer: 2 select lines $\Rightarrow$ D

Answer: (D) Go Back to Q18

Q19.

Solution

Concept – two's-complement representation of a negative integer: Take the positive value, invert every bit, then add one.

Step 1 – write $+5$ in 8 bits: $+5 = 0000\,0101$

Step 2 – invert every bit (one's complement): $0000\,0101 \rightarrow 1111\,1010$

Step 3 – add one: $1111\,1010 + 1 = 1111\,1011$

Step 4 – state the result: $-5 = 1111\,1011$ in 8-bit two's complement. (The leading 1 correctly marks it as negative.)

Why the other options are wrong:

- B, $0000\,0101$: is $+5$, not -5.
- C, $1111\,1010$: is the one's complement, missing the final $+1$.
- D, $1000\,0101$: is a sign-magnitude form, not two's complement.

Final Answer: $1111\,1011 \Rightarrow$ A

Answer: (A) Go Back to Q19

Q20.

Solution

Concept – output of a Wheatstone bridge under a small unbalance: Starting from balance, a small change in one arm produces a nearly linear output.

Step 1 – write the bridge output for equal arms R with one arm $R + \Delta R$: $V_o = V_{ex}\left(\dfrac{R+\Delta R}{2R+\Delta R} - \dfrac{1}{2}\right)$.

Step 2 – combine into one fraction: $V_o = V_{ex} \cdot \dfrac{\Delta R}{2(2R+\Delta R)}$.

Step 3 – apply the small-change approximation: For $\Delta R \ll R$, the denominator $\approx 4R$, so $V_o \approx \dfrac{V_{ex}}{4} \cdot \dfrac{\Delta R}{R}$.

Step 4 – read off the proportionality: The output is proportional to $\dfrac{\Delta R}{R}$ (first order, linear).

Why the other options are wrong:

- A, $(\Delta R/R)^2$: is only the tiny second-order nonlinearity.
- C, $R/\Delta R$: is inverted and diverges as $\Delta R \rightarrow 0$.
- D, constant: a balanced bridge gives zero output when $\Delta R = 0$.

Final Answer: $V_o \propto \dfrac{\Delta R}{R} \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q20

Q21.

Solution

Concept – output of a quarter-bridge strain-gauge circuit: $V_o = \dfrac{V_{ex}}{4}(\text{GF} \cdot \varepsilon)$, where $\dfrac{\Delta R}{R} = \text{GF} \cdot \varepsilon$.

Step 1 – list the data: $V_{ex} = 6$ V, GF $= 2.0$, $\varepsilon = 2000\ \mu\varepsilon = 2 \times 10^{-3}$.

Step 2 – compute the fractional resistance change: $\dfrac{\Delta R}{R} = \text{GF} \cdot \varepsilon = 2.0 \times 2 \times 10^{-3} = 4 \times 10^{-3}$

Step 3 – multiply by $\dfrac{V_{ex}}{4}$: $\dfrac{V_{ex}}{4} = \dfrac{6}{4} = 1.5$ V

Step 4 – form the output: $V_o = 1.5 \times 4 \times 10^{-3}$

$V_o = 6 \times 10^{-3}$ V $= 6$ mV

Why the other options are wrong:

- A, 3 mV: halves the correct strain or excitation.
- B, 12 mV: omits the factor of $\frac{1}{4}$ (uses $\frac{1}{2}$ instead).
- D, 1.5 mV: leaves out the gauge factor.

Final Answer: $V_o = 6$ mV $\Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q21

Q22.

Solution

Concept – gain of a three-op-amp instrumentation amplifier: $A_d = 1 + \dfrac{2R}{R_G}$, set by one external gain resistor.

Step 1 – list the data: $R = 25\ \text{k}\Omega$, $R_G = 1\ \text{k}\Omega$.

Step 2 – form the ratio $\dfrac{2R}{R_G}$: $\dfrac{2 \times 25\ \text{k}\Omega}{1\ \text{k}\Omega} = \dfrac{50\ \text{k}\Omega}{1\ \text{k}\Omega} = 50$

Step 3 – add the 1: $A_d = 1 + 50$

$A_d = 51$

Why the other options are wrong:

- A, 50: forgets the leading $+1$ in the formula.
- C, 26: uses $\frac{R}{R_G}$ instead of $\frac{2R}{R_G}$.
- D, 101: doubles the ratio incorrectly (uses $4R/R_G$).

Final Answer: $A_d = 51 \Rightarrow$ B

Answer: (B) Go Back to Q22

Q23.

Solution

Concept – relation between CMRR, differential gain and common-mode gain: $\text{CMRR} = \frac{A_d}{A_c}$, and in decibels $\text{CMRR}_{\text{dB}} = 20\log_{10}\frac{A_d}{A_c}$.

Step 1 – convert the CMRR from dB to a ratio: $100 = 20\log_{10}(\text{CMRR})$, so $\log_{10}(\text{CMRR}) = 5$, giving $\text{CMRR} = 10^5$.

Step 2 – rearrange for the common-mode gain: $A_c = \frac{A_d}{\text{CMRR}}$

Step 3 – substitute the values: $A_c = \frac{500}{10^5}$

Step 4 – simplify: $A_c = 5 \times 10^{-3} = 0.005$

Why the other options are wrong:

- B, 0.05 and C, 0.5: use a CMRR ratio $10\times$ or $100\times$ too small.
- D, 5: would require CMRR $= 100$, i.e. only 40 dB.

Final Answer: $A_c = 0.005 \Rightarrow$ A

Answer: (A) Go Back to Q23

Q24.

Solution

Concept – nature of the piezoelectric signal: A piezoelectric crystal produces charge in response to a *change* in mechanical stress, and that charge leaks away for a static load.

Step 1 – note the transduction mechanism: Deforming the crystal displaces bound charge, generating a voltage only while the deformation is changing.

Step 2 – consider a static load: Under a constant force the generated charge slowly bleeds off through the finite input resistance, so steady (DC) quantities cannot be held.

Step 3 – match to the best application: Rapidly varying quantities, such as heart sounds, arterial pressure pulses or ultrasound, are ideal for a piezoelectric sensor.

Why the other options are wrong:

- A, C, D: all involve static or DC quantities, which a piezoelectric device cannot hold.

Final Answer: dynamic (time-varying) pressure or force $\Rightarrow$ B

Answer: (B) Go Back to Q24

Q25.

Solution

Concept – polarisable versus non-polarisable electrodes: A good biopotential electrode should let charge cross the electrode–electrolyte interface freely, giving a stable contact potential.

Step 1 – classify the Ag/AgCl electrode: Its reversible Ag $\rightleftharpoons$ AgCl reaction allows charge to pass easily, making it nearly non-polarisable.

Step 2 – see the benefit: A stable half-cell potential means small DC drift and, crucially, low motion (movement) artefact, which is vital for ECG/EEG.

Step 3 – select the matching statement: The electrode is nearly non-polarisable with a stable contact potential and low motion artefact.

Why the other options are wrong:

- A: with gel, its contact impedance is actually low.
- B: a strongly polarisable electrode would be a poor recording electrode, the opposite of Ag/AgCl.
- D: it does not act as a temperature transducer.

Final Answer: nearly non-polarisable, stable, low-artefact $\Rightarrow$ C

Answer: (C) Go Back to Q25

Q26.

Solution

Concept – the Pan–Tompkins QRS detection pipeline: The algorithm shapes the ECG so the QRS stands out sharply before a threshold is applied.

Step 1 – first stage, band-pass filter: A band-pass (about 5–15 Hz) filter suppresses baseline wander, P and T waves, and high-frequency noise, keeping the QRS energy.

Step 2 – second stage, derivative: Differentiation measures the slope, which is largest during the steep QRS.

Step 3 – third stage, squaring: Squaring makes every sample positive and non-linearly boosts the large QRS slopes.

Step 4 – fourth stage, moving-window integration: A sliding-window integrator produces a smooth pulse whose width and height mark the QRS for thresholding.

Step 5 – read the order: band-pass $\rightarrow$ derivative $\rightarrow$ squaring $\rightarrow$ moving-window integration.

Final Answer: band-pass, derivative, squaring, integration $\Rightarrow$ $\boxed{\text{A}}$

Answer: (A) Go Back to Q26

Q27.

Solution

Concept – purpose of the squaring stage: Squaring is a point-by-point nonlinear operation on the differentiated signal.

Step 1 – effect on sign: $(\cdot)^2$ makes every sample non-negative, so positive and negative slopes both contribute positively.

Step 2 – effect on amplitude: Squaring amplifies large values much more than small ones, so the big QRS slopes are boosted far above baseline noise.

Step 3 – combine: The stage makes the signal all-positive and non-linearly emphasises the dominant QRS slopes, improving detection.

Why the other options are wrong:

- B: baseline wander is removed earlier, by the band-pass filter.
- C: squaring does not change the sampling rate.
- D: the operation is nonlinear and amplifying, not a uniform attenuation.

Final Answer: makes samples positive and emphasises QRS slopes $\Rightarrow$ $\boxed{\text{A}}$

Answer: (A) Go Back to Q27

Q28.

Solution

Concept – heart rate from the R–R interval: $\text{HR (beats/min)} = \dfrac{60}{\text{R–R interval in seconds}}$.

Step 1 – list the data: R–R interval $= 0.8$ s.

Step 2 – substitute: $\text{HR} = \dfrac{60}{0.8}$

Step 3 – divide: $\text{HR} = 75$ beats/min

Why the other options are wrong:

- A, 60: would need a 1.0 s interval.
- C, 80: would need a 0.75 s interval.
- D, 48: would need a 1.25 s interval.

Final Answer: $\text{HR} = 75$ beats/min $\Rightarrow$ B

Answer: (B) Go Back to Q28

Q29.

Solution

Concept – what differentiation extracts from the ECG: The derivative operator responds to how fast the signal is changing.

Step 1 – recall the derivative meaning: $\dfrac{dx}{dt}$ is the instantaneous slope of the waveform.

Step 2 – locate the steepest slopes on the ECG: The QRS complex has the fastest up- and down-strokes of the entire ECG, so it gives the largest derivative.

Step 3 – conclude the extracted feature: The derivative stage therefore extracts the slope (rate of change) of the QRS, the feature the detector keys on.

Why the other options are wrong:

- B: area is obtained by integration, not differentiation.
- C: a DC offset differentiates to zero and is discarded.
- D: noise is suppressed by the earlier band-pass stage, not extracted here.

Final Answer: slope (rate of change) of the QRS $\Rightarrow$ A

Answer: (A) Go Back to Q29

Q30.

Solution

Concept – diagnostic bandwidth of the clinical ECG: The recording band must be wide enough to preserve the low-frequency ST segment and the sharp QRS.

Step 1 – fix the low-frequency edge: A very low corner near 0.05 Hz is needed so the slow ST segment and T wave are not distorted.

Step 2 – fix the high-frequency edge: An upper corner near 100–150 Hz preserves the fast QRS edges in diagnostic mode.

Step 3 – state the standard band: The recommended diagnostic ECG bandwidth is about 0.05 Hz to 100 Hz.

Why the other options are wrong:

- A, 0.5–5 Hz: is far too narrow and would smear the QRS and ST segment.
- B, 100 Hz–1 kHz: misses the essential low-frequency ECG content.
- C, 1–10 Hz: is a monitoring-only band, not diagnostic.

Final Answer: 0.05 Hz to 100 Hz $\Rightarrow$ D

Answer: (D) Go Back to Q30

Q31.

Solution

Concept – the detector chain of a gamma (Anger) camera: Each gamma photon is first converted to light, then that light is turned into an electrical signal.

Step 1 – identify the light-producing element: A large thallium-activated sodium iodide crystal, NaI(Tl), absorbs the gamma photon and emits a burst of visible light (scintillation).

Step 2 – note what follows: The photomultiplier tubes behind the crystal then convert this light into electrical pulses; they do not create the scintillation.

Step 3 – select the converter: The gamma-to-light conversion is done by the NaI(Tl) scintillation crystal.

Why the other options are wrong:

- A, photomultiplier: converts *light* to electricity, a later step.

- B, collimator: only selects photon direction.
- C, pulse-height analyser: sorts electrical pulses by energy at the end of the chain.

Final Answer: NaI(Tl) scintillation crystal $\Rightarrow$ D

Answer: (D) Go Back to Q31

Q32.

Solution

Concept – function of the collimator in a gamma camera: A lead collimator has fine parallel holes that mechanically select photon direction.

Step 1 – see what reaches the crystal: Only gamma photons travelling nearly parallel to the holes pass through; obliquely travelling photons are absorbed by the lead septa.

Step 2 – link direction to the image: By accepting only defined directions, the collimator maps each detected event to a known line of origin, forming the projection image.

Step 3 – note the resolution trade-off: The hole size and length set the spatial resolution (and sensitivity) of the camera.

Why the other options are wrong:

- A: light-to-electricity conversion is the PMT's job.
- C: the collimator absorbs, it does not amplify, light.
- D: it filters gamma-ray *direction*, not visible light.

Final Answer: accepts only defined-direction photons, forming the image $\Rightarrow$ B

Answer: (B) Go Back to Q32

Q33.

Solution

Concept – the workhorse SPECT radionuclide: The ideal SPECT tracer emits a single gamma of moderate energy with a convenient half-life.

Step 1 – match the stated properties: A 140 keV gamma and a $\sim$ 6-hour half-life are the signature of technetium-99m (^{99m}Tc).

Step 2 – note why it dominates: 140 keV is well suited to NaI(Tl) detection and

collimation, the 6-hour half-life limits patient dose, and it is easily eluted from a ^{99}Mo/^{99m}Tc generator.

Why the other options are wrong:

- A, F-18: is a PET positron emitter (~ 110 min half-life), not a SPECT gamma emitter.
- B, I-131: emits high-energy gammas plus beta particles, giving high dose.
- D, Tl-201: is used in cardiac SPECT but emits lower-energy X-rays and has a longer half-life; it is not the most widely used tracer.

Final Answer: technetium-99m $\Rightarrow$ C

Answer: (C) Go Back to Q33

Q34.

Solution

Concept – tomographic reconstruction from rotating gamma projections: Acquiring planar views at many angles allows a 3-D reconstruction.

Step 1 – identify the acquisition: One or more gamma-camera heads rotate around the patient, recording planar projections at many angles.

Step 2 – identify the processing: These projections are back-projected/reconstructed into cross-sectional slices, exactly the single-photon emission computed tomography idea.

Step 3 – name the modality: This is SPECT.

Why the other options are wrong:

- A, planar X-ray: gives a single 2-D projection, not tomographic slices.
- B, A-mode ultrasound: is a 1-D depth trace.
- C, fluoroscopy: is real-time 2-D X-ray, not gamma tomography.

Final Answer: SPECT $\Rightarrow$ D

Answer: (D) Go Back to Q34

Q35.

Solution

Concept – role of the photomultiplier tubes in the Anger camera: The PMT array turns each scintillation into electrical signals that also encode where it happened.

Step 1 – sense the light: Each scintillation flash is shared among nearby PMTs, whose photocathodes convert light to electrons.

Step 2 – amplify: The dynode chain multiplies the electrons, giving a measurable pulse.

Step 3 – extract position and energy: The relative pulse sizes across the PMTs are combined (Anger logic) to give the (X, Y) position, and their sum gives the event energy for pulse-height selection.

Why the other options are wrong:

- B: collimation is done by the lead collimator, not the PMTs.
- C: the gamma photons come from the patient's tracer, not the PMTs.
- D: PMTs do not cool the crystal.

Final Answer: sense/amplify light, give position and energy $\Rightarrow$ $\boxed{\text{A}}$

Answer: (A) Go Back to Q35

Q36.

Solution

Concept – failure under repeated cyclic loading: Cyclic stresses can nucleate and grow cracks even when each cycle stays below the static strength.

Step 1 – describe the loading on an implant: A hip or knee implant sees millions of load cycles per year from walking.

Step 2 – describe the damage process: Micro-cracks initiate at stress concentrations and grow a little each cycle until final fracture.

Step 3 – name the mechanism: Progressive failure at stresses below the ultimate tensile strength, caused by repeated loading, is fatigue.

Why the other options are wrong:

- A, creep: is slow deformation under a *sustained constant* load, usually at high temperature.
- C, yielding: is a single-event onset of plastic deformation, not cyclic crack

growth.

- D, corrosion: is chemical attack; it may worsen fatigue but is not the cyclic-loading mechanism itself.

Final Answer: fatigue $\Rightarrow$ B

Answer: (B) Go Back to Q36

Q37.

Solution

Concept – representing fatigue data: Fatigue behaviour is summarised by plotting the stress amplitude against cycles to failure.

Step 1 – read the axes: The vertical axis is the cyclic stress amplitude S; the horizontal axis is the number of cycles to failure N (usually on a log scale).

Step 2 – identify the plot: A curve of S versus N is the classic S–N curve, also called the Wöhler curve.

Step 3 – note its use: It shows that lower stress amplitudes allow many more cycles before failure, and it reveals the endurance limit.

Why the other options are wrong:

- A, stress–strain curve: is a single monotonic loading test, not cyclic life.
- B, creep curve: plots strain versus time under constant load.
- C, hysteresis loop: is one stress–strain cycle, not the life curve.

Final Answer: S–N (Wöhler) curve $\Rightarrow$ D

Answer: (D) Go Back to Q37

Q38.

Solution

Concept – the endurance (fatigue) limit: Some materials show a stress amplitude below which fatigue life becomes effectively infinite.

Step 1 – read the flat part of the S–N curve: Below a certain stress amplitude the curve becomes horizontal, meaning failure no longer occurs however many cycles are applied.

Step 2 – name that stress: This threshold is the endurance limit (fatigue limit).

Step 3 – design implication: Keeping the working stress of an implant below its

endurance limit protects it against fatigue fracture.

Why the other options are wrong:

- A, ultimate tensile strength: is the single-load breaking stress, far above the endurance limit.
- C, yield strength: marks the onset of plastic flow under static load.
- D, proportional limit: is where the stress–strain curve stops being linear.

Final Answer: endurance (fatigue) limit $\Rightarrow$ $\boxed{\text{B}}$

Answer: (B) Go Back to Q38

Q39.

Solution

Concept – wear at a metal-on-polyethylene joint: The softer polyethylene surface is worn away by sliding contact with the harder metal head.

Step 1 – identify the contacting materials: A hard metal (or ceramic) femoral head articulates against a UHMWPE cup.

Step 2 – identify the wear mode: Sliding causes adhesion of polymer to the counterface and abrasion by asperities, releasing micrometre-scale polyethylene wear particles.

Step 3 – note the clinical effect: These particles provoke osteolysis (bone loss) and are a leading cause of long-term implant loosening.

Why the other options are wrong:

- A: cement fatigue is a separate issue, not the articulating-surface wear.
- C: galvanic corrosion is an electrochemical metal process, not the polymer wear here.
- D: thermal expansion is negligible at body temperature.

Final Answer: adhesive/abrasive wear of the polyethylene $\Rightarrow$ $\boxed{\text{B}}$

Answer: (B) Go Back to Q39

Q40.

Solution

Concept – the standard low-friction bearing polymer: Joint replacements pair a hard head with a tough, low-friction polymer liner.

Step 1 – recall the required properties: The liner needs low friction, high wear resistance, toughness and biocompatibility.

Step 2 – name the material: Ultra-high-molecular-weight polyethylene (UHMWPE) meets these needs and is the long-standing bearing material for hip and knee cups.

Why the other options are wrong:

- A, PMMA: is the bone *cement* that fixes the implant, not the bearing.
- B, PTFE: was tried early but wore out rapidly and failed clinically.
- C, silicone: is used for soft small-joint spacers, not load-bearing hip/knee bearings.

Final Answer: UHMWPE $\Rightarrow$ D

Answer: (D) Go Back to Q40

Q41.

Solution

Concept – axial (normal) stress: $\sigma = \dfrac{F}{A}$, the force divided by the cross-sectional area.

Step 1 – list the data in base units: $F_{max} = 2000$ N, $A = 200$ mm^2 $= 200 \times 10^{-6}$ m^2 $= 2 \times 10^{-4}$ m^2.

Step 2 – substitute into the stress formula: $\sigma = \dfrac{2000}{2 \times 10^{-4}}$

Step 3 – divide the coefficients: $\dfrac{2000}{2} = 1000$

Step 4 – handle the power of ten: $\dfrac{1}{10^{-4}} = 10^4$, so $\sigma = 1000 \times 10^4 = 10^7$ Pa

Step 5 – express in MPa: $\sigma = 10^7$ Pa $= 10$ MPa

Why the other options are wrong:

- A, 5 MPa: uses half the load.
- C, 20 MPa: uses half the area.
- D, 100 MPa: is off by a factor of ten in the area conversion.

Final Answer: $\sigma = 10$ MPa $\Rightarrow$ B

Answer: (B) Go Back to Q41

Q42.

Solution

Concept – open-loop versus closed-loop control: A system that measures its output and feeds it back to correct the input is closed-loop.

Step 1 – identify the measured output: The depth-of-anaesthesia (BIS-type) index is continuously measured from the patient.

Step 2 – identify the corrective action: The controller compares this measured index with the target and adjusts the infusion rate to reduce the difference (error).

Step 3 – classify the loop: Feeding the measured output back to drive the actuator toward the target is negative-feedback (closed-loop) control.

Why the other options are wrong:

- A, open-loop: would set the infusion without measuring the patient's response.
- B, feedforward: acts on a disturbance estimate only, without output feedback.
- D, uncontrolled: has no automatic regulation at all.

Final Answer: negative-feedback (closed-loop) control $\Rightarrow$ C

Answer: (C) Go Back to Q42

Q43.

Solution

Concept – unit conversion of flow rate: Convert millilitres per hour to millilitres per minute by dividing by 60.

Step 1 – list the data: Flow rate $= 6$ mL/h.

Step 2 – note that 1 hour $= 60$ minutes: 6 mL are delivered over 60 minutes.

Step 3 – divide: $\dfrac{6 \text{ mL}}{60 \text{ min}} = 0.1$ mL/min

Why the other options are wrong:

- A, 1 mL/min: divides by 6 instead of 60.
- C, 0.6 mL/min: divides by 10.

- D, 60 mL/min: multiplies by 10 instead of dividing by 60.

Final Answer: 0.1 mL/min $\Rightarrow$ B

Answer: (B) Go Back to Q43

Q44.

Solution

Concept – first-order decay and the time constant: For $C(t) = C_0\, e^{-t/\tau}$, after one time constant the value falls to $e^{-1} \approx 0.368$ of the start.

Step 1 – recall the meaning of 37%: $e^{-1} = 0.368 \approx 37\%$, reached at $t = \tau$ (one time constant).

Step 2 – read the given time constant: $\tau = 4$ hours.

Step 3 – state the time: The plasma concentration falls to about 37% after $t = \tau = 4$ hours.

Why the other options are wrong:

- A, 2 h: is half a time constant, giving $\approx 61\%$, not 37%.
- C, 8 h: is two time constants, giving $\approx 13.5\%$.
- D, 1 h: is a quarter time constant, giving $\approx 78\%$.

Final Answer: $t = 4$ hours $\Rightarrow$ B

Answer: (B) Go Back to Q44

Q45.

Solution

Concept – steady-state error of a type-0 unity-feedback system: For a step input, $e_{ss} = \dfrac{1}{1+K}$, where K is the open-loop DC gain (position error constant).

Step 1 – list the data: $K = 99$.

Step 2 – substitute into the formula: $e_{ss} = \dfrac{1}{1+99}$

Step 3 – add in the denominator: $1 + 99 = 100$

Step 4 – take the reciprocal: $e_{ss} = \dfrac{1}{100} = 0.01$

Step 5 – interpret: Higher loop gain gives smaller steady-state error, so a large K makes the controller track the anaesthesia target closely.

Why the other options are wrong:

- A, 0.5: would need $K = 1$.
- B, 0.99: confuses the error with the fed-back fraction.
- C, 0.1: would need $K = 9$.

Final Answer: $e_{ss} = 0.01 \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q45

Q46.

Solution

Concept – IV drip rate calculation: $\text{drip rate} = \dfrac{\text{total volume} \times \text{drop factor}}{\text{total time in minutes}}$.

Step 1 – find the total number of drops: Total drops $= 500$ mL $\times$ 20 drops/mL $=$ 10000 drops.

Step 2 – convert the time to minutes: 5 hours $= 5 \times 60 = 300$ minutes.

Step 3 – divide drops by minutes: $\text{drip rate} = \dfrac{10000}{300}$

Step 4 – evaluate: drip rate $= 33.3 \approx 33$ drops/min

Why the other options are wrong:

- A, 20 drops/min: would empty the bag too slowly (over about 8.3 h).
- B, 100 drops/min: would finish in about 100 min.
- C, 50 drops/min: would finish in about 200 min, not 300.

Final Answer: ≈ 33 drops/min $\Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q46

Answer Key

Q	Ans	Q	Ans	Q	Ans	Q	Ans	Q	Ans
1	C	2	C	3	A	4	C	5	A
6	C	7	C	8	D	9	D	10	A
11	A	12	D	13	A	14	C	15	B
16	C	17	A	18	D	19	A	20	B
21	C	22	B	23	A	24	B	25	C
26	A	27	A	28	B	29	A	30	D
31	D	32	B	33	C	34	D	35	A
36	B	37	D	38	B	39	B	40	D
41	B	42	C	43	B	44	B	45	D
46	D								