GATE Biomedical Engineering

Sample Paper – 5

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 (cardiac resting membrane potential ≈ -90 mV, proton gyromagnetic ratio ≈ 42.58 MHz/T) unless stated otherwise.

Human Anatomy and Physiology

Q1. In a skeletal muscle fibre, the immediate molecular trigger that starts cross-bridge cycling between actin and myosin is the binding of which ion to troponin C? **[1 mark]**

(A) calcium ions (Ca^{2+})

(B) sodium ions (Na^{+})

(C) potassium ions (K^{+})

(D) chloride ions (Cl^-)

Q2. The prolonged plateau (phase 2) of the ventricular cardiac action potential, which is absent in a nerve action potential, is produced mainly by the sustained inward flow of: **[1 mark]**

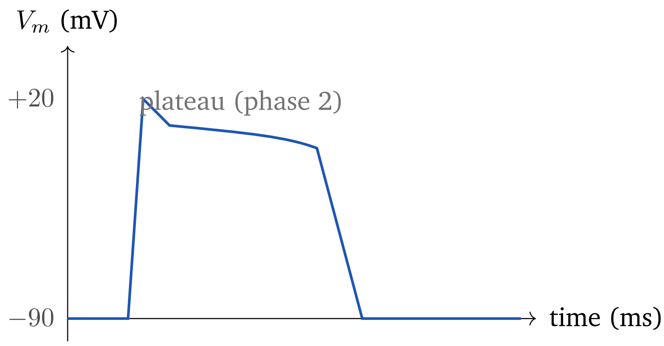
(A) sodium ions through fast Na^+ channels

(B) potassium ions through delayed rectifier channels

(C) calcium ions through L-type Ca^{2+} channels

(D) chloride ions through leak channels

Q3. The trace below shows a single ventricular cardiac action potential with its characteristic long plateau. Because the absolute refractory period lasts almost the entire action potential, cardiac muscle is protected against: **[1 mark]**



(A) forming a resting potential

(B) conducting the impulse to the next cell

(C) repolarising back to rest

(D) summation into a sustained tetanic contraction

Q4. In a skeletal muscle fibre, the membrane structure that carries the surface action potential deep into the interior of the fibre so that calcium release is triggered simultaneously throughout its volume is the: **[1 mark]**

(A) transverse (T) tubule

(B) myosin thick filament

(C) Golgi apparatus

(D) motor end plate

Q5. The neurotransmitter released at the skeletal neuromuscular junction that binds nicotinic receptors on the motor end plate to depolarise the muscle fibre is: **[1 mark]**

(A) noradrenaline

(B) dopamine

(C) acetylcholine

(D) glutamate

Q6. The stable resting membrane potential of a human ventricular cardiac muscle cell (more negative than that of a typical neuron) is nearest to: **[1 mark]**

(A) -55 mV

(B) 0 mV

(C) $+30$ mV

(D) -90 mV

Electric Circuits, Signals and Systems

Q7. For a linear two-port network described by its impedance (z) parameters, the parameter z_{11} is defined as: **[1 mark]**

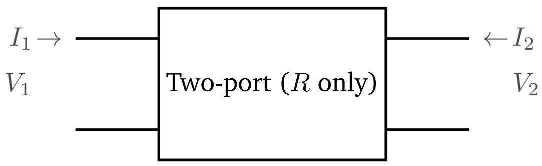
(A) $\frac{V_1}{I_2}$ with $I_1 = 0$

(B) $\frac{V_1}{I_1}$ with $I_2 = 0$ (output open-circuited)

(C) $\frac{I_1}{V_1}$ with $V_2 = 0$

(D) $\frac{V_2}{V_1}$ with $I_2 = 0$

Q8. The passive two-port network shown contains only resistors and is therefore reciprocal. For such a network the impedance (z) parameters must satisfy: **[1 mark]**



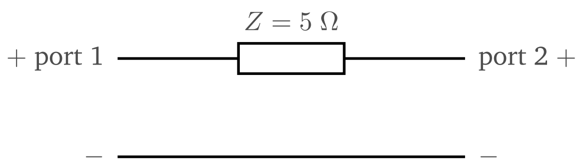
(A) $z_{11} = z_{22}$

(B) $z_{12} = z_{21}$

(C) $z_{11} = z_{12}$

(D) $z_{21} = z_{22}$

Q9. The two-port shown consists of a single series impedance $Z = 5\ \Omega$ between the two ports. Its transmission (ABCD) parameters are $A = 1$, $C = 0$, $D = 1$, and B equal to the series impedance. The value of the parameter B is: **[1 mark]**



(A) 0

(B) 1

(C) $\frac{1}{5}$ S

(D) $5\ \Omega$

Q10. For a two-port network, the admittance (y) parameter matrix is related to the impedance (z) parameter matrix by: **[1 mark]**

(A) $[Y] = [Z]^{-1}$ (matrix inverse)

(B) $[Y] = [Z]^T$ (transpose)

(C) $[Y] = [Z]$

(D) $[Y] = -[Z]$

Q11. A two-port network is said to be *symmetrical* when the two ports can be interchanged without altering the network's terminal behaviour. For a symmetrical two-port, the impedance parameters satisfy: **[1 mark]**

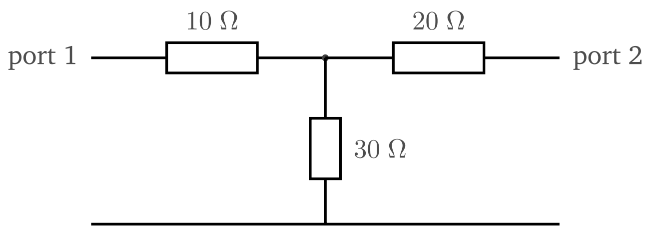
(A) $z_{12} = 0$

(B) $z_{11} = -z_{22}$

(C) $z_{11} = z_{22}$

(D) $z_{21} = 0$

Q12. For the resistive T-network shown, the two series arms are $10\ \Omega$ (at port 1) and $20\ \Omega$ (at port 2), and the shunt arm is $30\ \Omega$. The impedance parameter z_{11}, equal to the port-1 series arm plus the shunt arm, is: **[1 mark]**



(A) $30\ \Omega$

(B) $50\ \Omega$

(C) $40\ \Omega$

(D) $60\ \Omega$

Q13. For the same T-network of the previous question, the transfer impedance $z_{12} = z_{21}$ equals the value of the shunt arm. Its value is: **[1 mark]**

(A) $10\ \Omega$

(B) $40\ \Omega$

(C) $20\ \Omega$

(D) $30\ \Omega$

Analog and Digital Electronics

Q14. A 555 timer integrated circuit connected in *astable* mode produces at its output a: **[1 mark]**

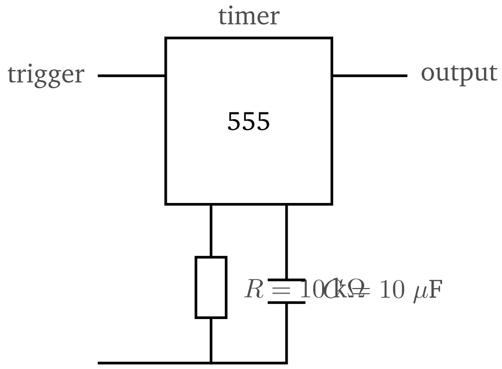
(A) continuous, free-running rectangular (square) wave

(B) single output pulse for each external trigger

(C) pure sinusoidal waveform

(D) constant DC voltage only

Q15. The 555 timer shown is wired in *monostable* (one-shot) mode with a timing resistor $R = 10$ kΩ and timing capacitor $C = 10$ μF. The width of the output pulse, $T = 1.1\,RC$, is: **[1 mark]**



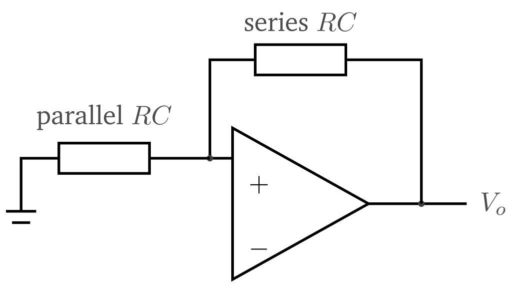
(A) 1.1 s

(B) 0.011 s

(C) 0.11 s

(D) 11 s

Q16. The Wien-bridge oscillator sketched below uses a series-RC and a parallel-RC network in its positive-feedback path. To just sustain oscillation, the non-inverting amplifier must supply a minimum voltage gain of: **[1 mark]**



(A) 1

(B) 3

(C) 2

(D) 29

Q17. For a feedback circuit to sustain steady sinusoidal oscillation, the Barkhausen criterion requires that the loop gain has a: **[1 mark]**

(A) magnitude equal to 1 and a total phase shift of $0°$ (or $360°$)

(B) magnitude greater than 1 and a phase shift of $90°$

(C) magnitude less than 1 and any phase

(D) magnitude of zero

Q18. In a three-section (three identical RC stages) RC phase-shift oscillator, the RC feedback network must contribute a total phase shift of: **[1 mark]**

(A) $90°$

(B) $60°$

(C) $180°$

(D) $360°$

Q19. Which LC oscillator determines its frequency using a tapped *capacitive* voltage divider (two series capacitors) across the tank inductor? **[1 mark]**

(A) Wien-bridge oscillator

(B) RC phase-shift oscillator

(C) Hartley oscillator

(D) Colpitts oscillator

Sensors, Bioinstrumentation and Measurements

Q20. A pulse oximeter estimates arterial oxygen saturation (SpO_2) by comparing the light absorbed by the finger at two optical wavelengths. The two wavelengths conventionally used are: **[1 mark]**

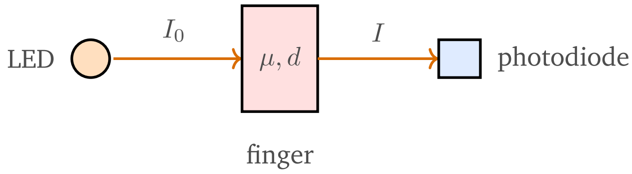
(A) ultraviolet (≈ 300 nm) and blue (≈ 450 nm)

(B) two identical red wavelengths

(C) green (≈ 530 nm) and yellow (≈ 580 nm)

(D) red (≈ 660 nm) and infrared (≈ 940 nm)

Q21. In the pulse-oximeter light path shown, the transmitted intensity follows the Beer–Lambert law $I = I_0 e^{-\mu d}$, where μ is the absorption coefficient and d the path length. If the measured transmitted intensity is $I = I_0/e^2$, then the product μd equals: **[2 marks]**



(A) 1

(B) 2

(C) 0.5

(D) e^2

Q22. Pulse oximetry can tell oxygenated from deoxygenated haemoglobin because, in the red part of the spectrum (around 660 nm), deoxyhaemoglobin absorbs: **[2 marks]**

(A) less red light than oxyhaemoglobin

(B) more red light than oxyhaemoglobin

(C) exactly the same amount as oxyhaemoglobin

(D) no red light at all

Q23. A linear optical displacement sensor used in a bioinstrumentation rig has a sensitivity of 10 mV per mm. During a measurement its output changes by 250 mV. The corresponding displacement is: **[2 marks]**

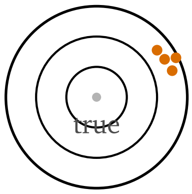
(A) 25 mm

(B) 2.5 mm

(C) 250 mm

(D) 0.25 mm

Q24. During calibration a sensor's repeated readings fall in a tight cluster (as sketched on the target) but the cluster sits consistently away from the true (centre) value. This sensor is best described as: **[2 marks]**



tight cluster, off-centre

(A) accurate but not precise

(B) both accurate and precise

(C) precise but not accurate

(D) neither accurate nor precise

Q25. While calibrating a pressure sensor, it reads 102 mmHg when the true applied pressure is exactly 100 mmHg. The percentage (relative) error of this reading is: **[2 marks]**

(A) 1%

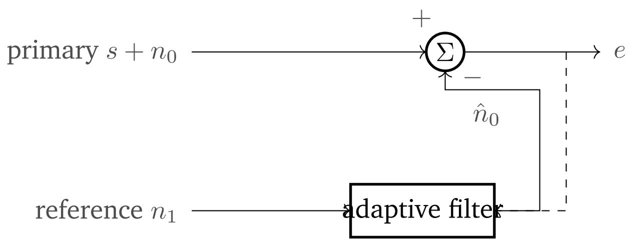
(B) 2%

(C) 0.2%

(D) 20%

Biomedical Signal Processing

Q26. The adaptive noise canceller sketched below is used to remove the strong maternal ECG from an abdominal recording so that the weak foetal ECG survives at the output. For the canceller to work, the *reference* input fed to the adaptive filter must be a signal that is: **[2 marks]**



(A) the clean foetal ECG itself

(B) random white noise unrelated to any source

(C) identical to the primary input

(D) correlated with the interfering noise but not with the desired foetal signal

Q27. In the Least-Mean-Squares (LMS) adaptive algorithm, the filter weight vector is updated at each step by an amount proportional to: **[2 marks]**

(A) the product of the instantaneous error and the input vector, $\mu\, e(n)\, \mathbf{x}(n)$

(B) the second time-derivative of the error

(C) the integral of the output over all past time

(D) a fixed constant independent of the error

Q28. In the LMS algorithm, increasing the adaptation step size μ while keeping it within its stable range generally: **[2 marks]**

(A) has no effect on the rate of convergence

(B) always drives the filter unstable immediately

(C) speeds up convergence but increases the steady-state error (misadjustment)

(D) slows convergence and lowers the misadjustment

Q29. An adaptive noise canceller is fed a pure 60 Hz sinusoid as its reference input to suppress power-line interference in an EEG. After the weights converge, the canceller behaves, as seen from the primary channel at 60 Hz, like a: **[2 marks]**

(A) all-pass filter

(B) notch (band-reject) filter tuned to 60 Hz

(C) low-pass filter

(D) high-pass filter

Q30. To pull a repeatable evoked potential out of noise, $N = 100$ identical stimulus trials are ensemble-averaged. Since the noise is uncorrelated across trials, the amplitude signal-to-noise ratio improves by a factor of $\sqrt{N}$. This factor is: **[2 marks]**

(A) 100

(B) 50

(C) 10

(D) 1000

Medical Imaging Systems

Q31. The gyromagnetic ratio of the hydrogen proton is 42.58 MHz/T. In a clinical MRI scanner with a static field of 1.5 T, the Larmor (resonance) frequency of the protons is nearest to: **[2 marks]**

(A) 64 MHz

(B) 128 MHz

(C) 21 MHz

(D) 300 MHz

Q32. In magnetic resonance imaging, the relaxation time constant that describes the *recovery of the longitudinal magnetization* (spin–lattice relaxation) is denoted: **[2 marks]**

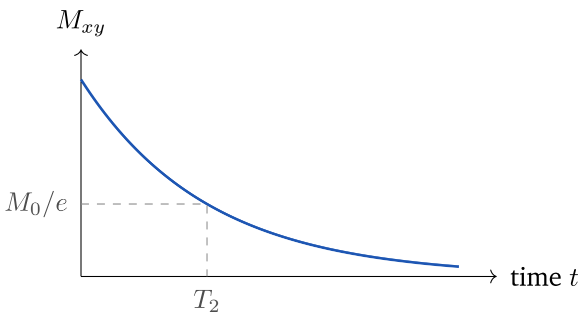
(A) T_2 (spin–spin relaxation)

(B) TE (echo time)

(C) TR (repetition time)

(D) T_1 (spin–lattice relaxation)

Q33. The transverse magnetization in MRI decays as $M_{xy} = M_0\, e^{-t/T_2}$, as sketched below. If $T_2 = 80$ ms, the time taken for the transverse magnetization to fall to $1/e$ (about 37%) of its initial value is: **[2 marks]**



(A) 40 ms

(B) 80 ms

(C) 160 ms

(D) 8 ms

Q34. An MRI pulse sequence that uses a *short* repetition time (TR) together with a *short* echo time (TE) produces an image whose contrast is predominantly: **[2 marks]**

(A) T_2-weighted

(B) T_1-weighted

(C) proton-density-weighted

(D) diffusion-weighted

Q35. In MRI, spatial localisation of the resonance signal along the three axes of the body is achieved by superimposing on the strong static field a set of: **[2 marks]**

(A) stronger permanent magnets only

(B) radio-frequency shields

(C) regions of higher proton density

(D) magnetic field gradient coils

Biomechanics and Biomaterials

Q36. When two dissimilar metals are used together in an implant (for example a stainless-steel screw in a cobalt-chromium plate) and are bathed in conductive body fluid, the accelerated electrochemical attack that develops at their junction is called: **[2 marks]**

(A) galvanic (bimetallic) corrosion

(B) elastic deformation

(C) work hardening

(D) annealing

Q37. Titanium alloys and 316L stainless steel resist corrosion inside the body chiefly because they spontaneously grow a thin, adherent, self-repairing surface layer of: **[2 marks]**

(A) a soft polymer coating

(B) loose flakes of rust

(C) deposited calcium phosphate

(D) a passive metal-oxide film

Q38. A Ti–6Al–4V implant with Young's modulus $E = 110$ GPa carries an axial stress of $\sigma = 55$ MPa, well within the elastic range. The elastic strain $\varepsilon = \sigma/E$ produced is: **[2 marks]**

(A) 0.005

(B) 0.0005

(C) 0.05

(D) 0.00005

Q39. A metallic hip stem is far stiffer than the surrounding bone, so it carries most of the load and the adjacent bone becomes under-loaded and gradually resorbs. This clinically important phenomenon is called: **[2 marks]**

(A) osseointegration

(B) stress shielding

(C) galvanic corrosion

(D) creep rupture

Q40. Which bioceramic is most commonly applied as a bioactive coating on orthopaedic and dental implants because its composition is close to that of natural bone mineral and it encourages direct bone bonding? **[2 marks]**

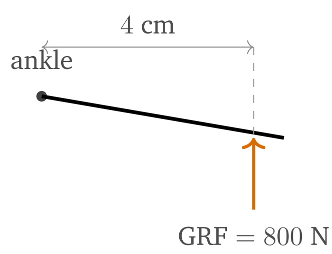
(A) hydroxyapatite

(B) silicone rubber

(C) ultra-high-molecular-weight polyethylene

(D) mild steel

Q41. The prosthetic foot shown carries a ground reaction force of 800 N acting 4 cm anterior to the ankle joint. Treating the ankle as the pivot, the moment (torque) of this force about the ankle is: **[2 marks]**



(A) 3.2 N·m

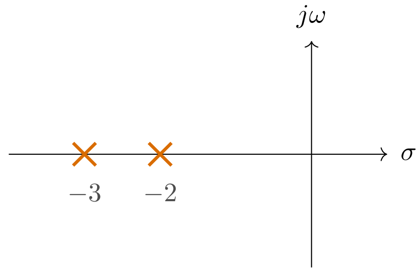
(B) 320 N·m

(C) 3200 N·m

(D) 32 N·m

Control Systems and Medical Instrumentation

Q42. A closed-loop control system has the characteristic equation $s^2 + 5s + 6 = 0$. As sketched on the s-plane, its two closed-loop poles are located at: **[2 marks]**



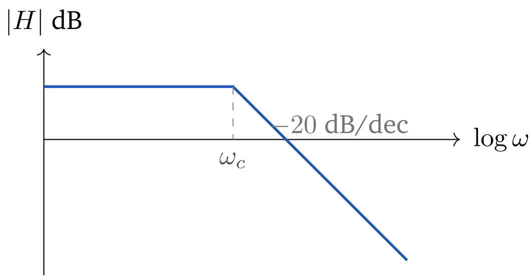
(A) $s = +2$ and $s = +3$

(B) $s = \pm j\,2.45$

(C) $s = -2$ and $s = -3$

(D) $s = -1$ and $s = -6$

Q43. The straight-line Bode magnitude plot shown belongs to a first-order low-pass transfer function $H(s) = \dfrac{1}{1 + s/\omega_c}$. Exactly at the corner frequency $\omega = \omega_c$, the phase shift introduced by this system is: **[2 marks]**



(A) $-45°$

(B) $0°$

(C) $-90°$

(D) $-180°$

Q44. The unit-step response of a control system has the Laplace transform $Y(s) = \dfrac{4}{s(s+2)}$. By the final-value theorem, the steady-state value $y(\infty)$ is: **[2 marks]**

(A) 4

(B) 0

(C) 2

(D) 1

Q45. For the characteristic equation $s^3 + 3s^2 + 3s + 1 = 0$, applying the Routh–Hurwitz criterion shows that the system is: [2 marks]

(A) stable (all poles in the left half-plane)

(B) marginally stable (poles on the imaginary axis)

(C) unstable with two right-half-plane poles

(D) unstable with one right-half-plane pole

Q46. In medical instrumentation, patient electrical safety in a mains-powered ECG amplifier is provided chiefly by an isolation amplifier, whose primary purpose is to: [2 marks]

(A) amplify only very small biopotentials

(B) break the direct electrical (galvanic) path between the patient and the mains-powered circuitry

(C) filter out 50/60 Hz interference

(D) raise the sampling rate of the recorder

Detailed Solutions

Q1.

Solution

Concept – excitation–contraction coupling in skeletal muscle: Contraction begins only when the myosin binding sites on actin are uncovered.

Step 1 – recall what blocks the binding sites at rest: At rest the tropomyosin strand lies over the actin binding sites, so myosin cannot attach.

Step 2 – identify the trigger ion: When the fibre is excited, Ca^{2+} is released from the sarcoplasmic reticulum into the cytosol.

Step 3 – follow the calcium action: The Ca^{2+} binds troponin C, which pulls tropomyosin aside and exposes the actin sites.

Step 4 – link to force generation: Myosin heads then attach and cycle, producing the sliding-filament contraction.

Why the other options are wrong:

- B and C, Na^+/K^+: carry the surface action potential but do not bind troponin.
- D, Cl^-: contributes to membrane stability, not cross-bridge triggering.

Final Answer: calcium ions bind troponin C $\Rightarrow$ $\boxed{A}$

Answer: (A) Go Back to Q1

Q2.

Solution

Concept – shape of the cardiac action potential: The ventricular action potential has a long plateau that a nerve spike lacks.

Step 1 – list the phases: Phase 0 is rapid Na^+ depolarisation, phase 1 a small notch, phase 2 the plateau, phase 3 repolarisation and phase 4 the resting level.

Step 2 – examine the plateau (phase 2): During the plateau a slow inward current almost balances the outward K^+ current, holding the membrane depolarised.

Step 3 – identify the inward current carrier: This slow inward current is carried by Ca^{2+} entering through L-type (long-lasting) calcium channels.

Step 4 – state the physiological role: The resulting calcium entry both prolongs the action potential and supplies calcium for contraction.

Why the other options are wrong:

- A, fast Na^+: causes the rapid upstroke (phase 0), not the plateau.
- B and D, K^+/Cl^- outward currents: end the plateau rather than sustain it.

Final Answer: inward Ca^{2+} through L-type channels $\Rightarrow \boxed{C}$

Answer: (C) Go Back to Q2

Q3.

Solution

Concept – refractory period and mechanical response: Whether a muscle can be re-excited before it relaxes decides if its twitches can fuse.

Step 1 – read the trace: The action potential stays depolarised through the long plateau, lasting a few hundred milliseconds.

Step 2 – match refractory period to the plateau: The absolute refractory period lasts almost the whole plateau, so a second impulse cannot fire until the cell has nearly relaxed.

Step 3 – connect to mechanics: Because a new contraction cannot start until relaxation is under way, individual twitches cannot pile up.

Step 4 – state the protective outcome: Cardiac muscle is therefore prevented from summating its twitches into a sustained tetanic contraction, which would stop it pumping.

Why the other options are wrong:

- A, B, C: resting potential, conduction and repolarisation all still occur normally.

Final Answer: it prevents tetanic summation $\Rightarrow \boxed{D}$

Answer: (D) Go Back to Q3

Q4.

Solution

Concept – rapid, uniform activation of a muscle fibre: A thick fibre must be depolarised throughout its interior at almost the same instant.

Step 1 – note the geometry problem: A surface action potential alone would reach the fibre core too slowly by diffusion.

Step 2 – identify the conducting structure: The transverse (T) tubules are inward folds of the surface membrane that penetrate the fibre.

Step 3 – describe their action: They carry the action potential deep inside, where they meet the sarcoplasmic reticulum at triads.

Step 4 – state the result: Calcium is then released throughout the fibre volume almost simultaneously, so contraction is uniform.

Why the other options are wrong:

- B, myosin filament: is the contractile motor, not a conductor.
- C, Golgi apparatus: is for protein processing.
- D, motor end plate: is the single input synapse on the surface, not the internal conductor.

Final Answer: transverse (T) tubule ⇒ A

Answer: (A) Go Back to Q4

Q5.

Solution

Concept – transmission at the neuromuscular junction: A motor neuron signals the muscle fibre chemically.

Step 1 – identify the junction: The skeletal neuromuscular junction is the synapse between a motor neuron and a muscle fibre.

Step 2 – name the transmitter released: The arriving nerve impulse releases acetylcholine from the nerve terminal.

Step 3 – describe its effect: Acetylcholine binds nicotinic receptors on the motor end plate, opening cation channels and depolarising the fibre.

Step 4 – note the clearing enzyme: Acetylcholinesterase then breaks it down so the fibre can reset.

Why the other options are wrong:

- A, noradrenaline: acts at sympathetic junctions.
- B, dopamine: is a central-nervous-system transmitter.
- D, glutamate: is the main excitatory transmitter in the brain, not at the skeletal junction.

Final Answer: acetylcholine ⇒ C

Answer: (C) Go Back to Q5

Q6.

Solution

Concept – resting potential differs between cell types: The resting level depends on the mix of ion channels a cell expresses.

Step 1 – recall the neuron value: A typical neuron rests near -70 mV.

Step 2 – compare with cardiac muscle: A ventricular cardiac muscle cell has a high resting K^+ permeability that pushes its resting potential more negative.

Step 3 – state the cardiac value: Its stable resting membrane potential is about -90 mV.

Why the other options are wrong:

- A, -55 mV: is near the firing threshold, not the resting level.
- B, 0 mV: means no charge separation.
- C, $+30$ mV: is the depolarised peak, not rest.

Final Answer: ≈ -90 mV $\Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q6

Q7.

Solution

Concept – open-circuit impedance parameters: The z-parameters relate the port voltages to the port currents through $V_1 = z_{11}I_1 + z_{12}I_2$ and $V_2 = z_{21}I_1 + z_{22}I_2$.

Step 1 – isolate z_{11}: Set $I_2 = 0$, which means the output port is left open-circuited.

Step 2 – read the defining equation: With $I_2 = 0$, the first equation reduces to $V_1 = z_{11}I_1$.

Step 3 – write the definition: $z_{11} = \left.\dfrac{V_1}{I_1}\right|_{I_2=0}$, the driving-point (input) impedance with the output open.

Why the other options are wrong:

- A, V_1/I_2: with $I_1 = 0$ is the reverse transfer impedance z_{12}.
- C, I_1/V_1: is an admittance, not z_{11}.
- D, V_2/V_1: is a voltage ratio, not a z-parameter.

Final Answer: $z_{11} = V_1/I_1$ with $I_2 = 0 \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q7

Q8.

Solution

Concept – reciprocity of passive networks: A network built only from resistors (and other bilateral elements) is reciprocal.

Step 1 – state the reciprocity property: For a reciprocal two-port, exciting port 1 and reading port 2 gives the same transfer as exciting port 2 and reading port 1.

Step 2 – translate into z-parameters: This equality of forward and reverse transfer impedance means $z_{12} = z_{21}$.

Step 3 – apply to the resistor network: Since the box holds only resistors, it is reciprocal, so $z_{12} = z_{21}$.

Why the other options are wrong:

- A, $z_{11} = z_{22}$: is the extra condition for *symmetry*, not reciprocity.
- C and D: mix a driving-point term with a transfer term and have no general basis.

Final Answer: $z_{12} = z_{21} \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q8

Q9.

Solution

Concept – ABCD parameters of a series element: The transmission parameters relate input to output by $V_1 = AV_2 + BI_2$ and $I_1 = CV_2 + DI_2$.

Step 1 – write the network relations: For a single series impedance Z, the same current flows in both ports, so $I_1 = I_2$, giving $C = 0$ and $D = 1$.

Step 2 – relate the voltages: The input voltage exceeds the output by the drop across Z: $V_1 = V_2 + ZI_2$.

Step 3 – match to the ABCD form: Comparing $V_1 = AV_2 + BI_2$ gives $A = 1$ and $B = Z$.

Step 4 – put in the number: $B = Z = 5\ \Omega$.

Why the other options are wrong:

- A, 0: would mean no series drop.
- B, 1: is the value of A and D, not B.
- C, $1/5$ S: has units of admittance, appropriate to C for a shunt element, not B.

Final Answer: $B = 5\,\Omega \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q9

Q10.

Solution

Concept – duality of z and y parameter sets: The z set writes voltages in terms of currents; the y set writes currents in terms of voltages.

Step 1 – write both in matrix form: $\mathbf{V} = [Z]\,\mathbf{I}$ and $\mathbf{I} = [Y]\,\mathbf{V}$.

Step 2 – substitute one into the other: From the first, $\mathbf{I} = [Z]^{-1}\mathbf{V}$.

Step 3 – compare with the y definition: Matching $\mathbf{I} = [Y]\mathbf{V}$ gives $[Y] = [Z]^{-1}$.

Step 4 – note the requirement: This holds whenever $[Z]$ is non-singular (its inverse exists).

Why the other options are wrong:

- B, transpose: is not the inverse in general.
- C, equality: has inconsistent units (ohms versus siemens).
- D, negative: has no basis.

Final Answer: $[Y] = [Z]^{-1} \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q10

Q11.

Solution

Concept – symmetry of a two-port: Symmetry means the two ports are electrically interchangeable.

Step 1 – state what interchangeability implies: If the ports can be swapped without changing behaviour, the driving-point impedance seen at each port must be identical.

Step 2 – translate into parameters: The port-1 driving-point impedance is z_{11} and the port-2 one is z_{22}, so symmetry requires $z_{11} = z_{22}$.

Step 3 – separate from reciprocity: Reciprocity ($z_{12} = z_{21}$) is a different property; a network can be reciprocal without being symmetrical.

Why the other options are wrong:

- A and D, $z_{12} = 0$ or $z_{21} = 0$: would mean no coupling between ports.

- B, $z_{11} = -z_{22}$: has no physical basis for a passive network.

Final Answer: $z_{11} = z_{22} \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q11

Q12.

Solution

Concept – z-parameters of a T-network: For a T (star) network with series arms Z_a, Z_b and shunt arm Z_c: $z_{11} = Z_a + Z_c$, $z_{22} = Z_b + Z_c$, and $z_{12} = z_{21} = Z_c$.

Step 1 – identify the arms: $Z_a = 10\ \Omega$ (port-1 series), $Z_b = 20\ \Omega$ (port-2 series), $Z_c = 30\ \Omega$ (shunt).

Step 2 – apply the z_{11} formula: $z_{11} = Z_a + Z_c$

Step 3 – substitute: $z_{11} = 10 + 30$

Step 4 – add: $z_{11} = 40\ \Omega$

Step 5 – interpret: With the output open ($I_2 = 0$), the current from port 1 flows through the $10\ \Omega$ series arm and then the $30\ \Omega$ shunt arm to ground, so the input impedance is their sum.

Final Answer: $z_{11} = 40\ \Omega \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q12

Q13.

Solution

Concept – transfer impedance of a T-network: The mutual (transfer) impedance is set by the arm shared between the two loops.

Step 1 – recall the formula: For the T-network, $z_{12} = z_{21} = Z_c$, the shunt arm.

Step 2 – reason physically: With port 1 open ($I_1 = 0$), a current I_2 injected at port 2 returns through the shunt arm, and the voltage it develops there appears at port 1.

Step 3 – substitute the shunt value: $z_{12} = Z_c = 30\ \Omega$.

Why the other options are wrong:

- A and C, $10\ \Omega/20\ \Omega$: are the series arms, which do not carry the open-port transfer current.
- B, $40\ \Omega$: is z_{11}, a driving-point term, not the transfer impedance.

Final Answer: $z_{12} = z_{21} = 30\ \Omega \Rightarrow \boxed{D}$

Answer: (D) Go Back to Q13

Q14.

Solution

Concept – 555 timer operating modes: The 555 can run as a monostable (one-shot) or as an astable (free-running) multivibrator.

Step 1 – recall the astable arrangement: In astable mode the capacitor charges and discharges repeatedly between the two internal comparator thresholds.

Step 2 – describe the resulting output: The output toggles high and low on its own, with no external trigger, giving a continuous rectangular (square) wave.

Step 3 – state the use: This makes the astable 555 a simple clock or tone generator.

Why the other options are wrong:

- B, one pulse per trigger: describes the monostable mode.
- C, sinusoid: a 555 produces sharp-edged pulses, not a sine.
- D, DC only: ignores the oscillation altogether.

Final Answer: continuous free-running square wave $\Rightarrow \boxed{A}$

Answer: (A) Go Back to Q14

Q15.

Solution

Concept – monostable pulse width of a 555: In one-shot mode the output pulse width is $T = 1.1\,RC$.

Step 1 – list the data in base units: $R = 10\ \text{k}\Omega = 10 \times 10^3\ \Omega$, $C = 10\ \mu\text{F} = 10 \times 10^{-6}$ F.

Step 2 – form the product RC: $RC = (10 \times 10^3)(10 \times 10^{-6})$

Step 3 – multiply the coefficients: $10 \times 10 = 100$

Step 4 – combine the powers of ten: $10^3 \times 10^{-6} = 10^{-3}$

Step 5 – assemble RC: $RC = 100 \times 10^{-3} = 0.1$ s

Step 6 – apply the factor 1.1: $T = 1.1 \times 0.1$

$T = 0.11$ s

Final Answer: $T = 0.11$ s $\Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q15

Q16.

Solution

Concept – gain condition of the Wien-bridge oscillator: At its oscillation frequency the Wien network passes the signal with a fixed attenuation, and the amplifier must exactly make up that loss.

Step 1 – evaluate the network at $\omega_0 = 1/RC$: At ω_0 the series-parallel RC network has zero phase shift and a voltage transfer of $\frac{1}{3}$.

Step 2 – apply the loop-gain condition: For sustained oscillation the amplifier gain A times the network transfer must equal 1: $A \times \frac{1}{3} = 1$.

Step 3 – solve for the gain: $A = 3$.

Step 4 – interpret: A non-inverting amplifier with $A = 1 + R_f/R_1 = 3$ (i.e. $R_f = 2R_1$) meets the requirement.

Why the other options are wrong:

- A, 1: would not overcome the network's $\frac{1}{3}$ attenuation.
- C, 2: is still below the required value.
- D, 29: is the gain needed by the three-section RC *phase-shift* oscillator, not the Wien bridge.

Final Answer: minimum gain $= 3 \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q16

Q17.

Solution

Concept – Barkhausen criterion: An oscillator is a feedback loop whose signal must reproduce itself each round trip.

Step 1 – state the magnitude condition: The loop gain magnitude must be exactly 1, so the signal neither grows nor decays once oscillation is established.

Step 2 – state the phase condition: The total phase shift around the loop must be $0°$ (equivalently $360°$), so the returning signal is in phase with itself.

Step 3 – combine: Both conditions together, $|A\beta| = 1$ with $\angle A\beta = 0°$, define sustained oscillation.

Why the other options are wrong:

- B, 90° phase: the returning signal would not reinforce the input.
- C, magnitude < 1: oscillations would die away.
- D, zero magnitude: no signal survives at all.

Final Answer: $|A\beta| = 1$, phase $0^\circ \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q17

Q18.

Solution

Concept – phase shift needed in an RC oscillator: An inverting amplifier already gives 180°; the feedback network must supply the rest to satisfy Barkhausen.

Step 1 – account for the amplifier phase: The inverting amplifier contributes 180° of the required 360°.

Step 2 – find the network's share: The RC feedback network must therefore provide the remaining 180°.

Step 3 – distribute across the sections: Three cascaded RC sections share this, each giving about 60° at the oscillation frequency, so $3 \times 60^\circ = 180^\circ$.

Why the other options are wrong:

- A, 90°: a single RC section cannot reach a full 90°, and the total needed is 180°.
- B, 60°: is the shift of just one of the three sections.
- D, 360°: double-counts the amplifier's own 180°.

Final Answer: total network shift $= 180^\circ \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q18

Q19.

Solution

Concept – identifying LC oscillators by their tank tap: Hartley and Colpitts oscillators differ in whether they tap the inductor or the capacitor.

Step 1 – recall the Colpitts tank: The Colpitts oscillator uses one inductor with two series capacitors, and the feedback is taken from the junction of the two capacitors (a capacitive divider).

Step 2 – contrast with Hartley: The Hartley oscillator instead uses two series inductors (a tapped inductor) with a single capacitor.

Step 3 – match the description: "Tapped capacitive voltage divider across the tank inductor" is the Colpitts arrangement.

Why the other options are wrong:

- A and B, Wien-bridge / RC phase-shift: are RC oscillators with no LC tank.
- C, Hartley: uses a tapped inductor, not a tapped capacitor.

Final Answer: Colpitts oscillator $\Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q19

Q20.

Solution

Concept – two-wavelength principle of pulse oximetry: SpO_2 is found from the different light absorption of oxy- and deoxyhaemoglobin.

Step 1 – recall why two wavelengths are needed: Oxyhaemoglobin and deoxyhaemoglobin absorb red and infrared light by different amounts, so two wavelengths let the device separate them.

Step 2 – state the standard wavelengths: Pulse oximeters use a red LED near 660 nm and an infrared LED near 940 nm.

Step 3 – outline the computation: The ratio of the pulsatile absorbances at the two wavelengths is calibrated against SpO_2.

Why the other options are wrong:

- A, UV/blue: is not used; it is strongly absorbed and can be harmful.
- B, two identical reds: cannot distinguish the two haemoglobin forms.
- C, green/yellow: are not the standard oximetry wavelengths.

Final Answer: red (≈ 660 nm) and infrared (≈ 940 nm) $\Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q20

Q21.

Solution

Concept – Beer–Lambert absorption: Transmitted intensity falls exponentially with the product of absorption coefficient and path length: $I = I_0 e^{-\mu d}$.

Step 1 – write the given condition: $I = \dfrac{I_0}{e^2}$, i.e. $\dfrac{I}{I_0} = e^{-2}$.

Step 2 – equate to the law: $e^{-\mu d} = e^{-2}$.

Step 3 – match the exponents: $-\mu d = -2$.

Step 4 – solve: $\mu d = 2$.

Why the other options are wrong:

- A, 1: would give $I = I_0/e$, not I_0/e^2.
- C, 0.5: gives $I = I_0/e^{0.5}$.
- D, e^2: confuses the exponent with the ratio itself.

Final Answer: $\mu d = 2 \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q21

Q22.

Solution

Concept – absorption spectra of the two haemoglobins: Red and infrared light are absorbed differently by oxy- and deoxyhaemoglobin, and this is what makes pulse oximetry possible.

Step 1 – look at the red region (≈ 660 nm): Here deoxyhaemoglobin has the higher extinction coefficient.

Step 2 – state the comparison: Therefore, at red wavelengths, deoxyhaemoglobin absorbs *more* light than oxyhaemoglobin.

Step 3 – connect to appearance and reading: This is why poorly oxygenated blood looks darker (bluish), and why a falling SpO_2 raises the red absorbance.

Why the other options are wrong:

- A, less: describes the infrared region, where the roles reverse.
- C, equal: would occur only at the isosbestic points, not at 660 nm.
- D, none: both forms absorb some red light.

Final Answer: deoxyhaemoglobin absorbs more red light $\Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q22

Q23.

Solution

Concept – sensor sensitivity relation: Output change = sensitivity × input change, so input = output change ÷ sensitivity.

Step 1 – list the data: Sensitivity $S = 10$ mV/mm, output change $\Delta V = 250$ mV.

Step 2 – rearrange for displacement: $x = \dfrac{\Delta V}{S}$

Step 3 – substitute: $x = \dfrac{250 \text{ mV}}{10 \text{ mV/mm}}$

Step 4 – divide: $x = 25$ mm

Step 5 – check the units: mV cancels, leaving mm, as expected for a displacement.

Final Answer: $x = 25 \text{ mm} \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q23

Q24.

Solution

Concept – accuracy versus precision: Precision is repeatability (how tight the cluster is); accuracy is closeness to the true value (how centred the cluster is).

Step 1 – read the tightness of the cluster: The readings sit close together, so the sensor is repeatable, i.e. precise.

Step 2 – read the position of the cluster: The cluster is displaced from the true centre, so it has a consistent bias, i.e. it is not accurate.

Step 3 – combine the two observations: Tight but off-centre means precise but not accurate.

Step 4 – note the remedy: A fixed bias like this can usually be removed by recalibrating (adding an offset correction).

Why the other options are wrong:

- A, accurate but not precise: would be a scattered cluster centred on the target.
- B, both: would be a tight cluster on the centre.
- D, neither: would be a scattered, off-centre cluster.

Final Answer: precise but not accurate $\Rightarrow$ C

Answer: (C) Go Back to Q24

Q25.

Solution

Concept – relative (percentage) error: $\%\ \text{error} = \dfrac{\text{measured} - \text{true}}{\text{true}} \times 100.$

Step 1 – list the data: Measured $= 102$ mmHg, true $= 100$ mmHg.

Step 2 – find the absolute error: $102 - 100 = 2$ mmHg.

Step 3 – divide by the true value: $\dfrac{2}{100} = 0.02.$

Step 4 – convert to a percentage: $0.02 \times 100 = 2\%.$

Final Answer: $2\% \Rightarrow$ B

Answer: (B) Go Back to Q25

Q26.

Solution

Concept – how an adaptive noise canceller works: The filter builds an estimate of the interference and subtracts it from the primary channel.

Step 1 – describe the two inputs: The primary input carries the desired foetal signal plus maternal-ECG interference; the reference input feeds the adaptive filter.

Step 2 – state what the filter must estimate: The filter forms an estimate of the interference so it can be subtracted at the summing junction.

Step 3 – deduce the reference requirement: For that estimate to be useful, the reference must be correlated with the interfering noise, yet uncorrelated with the desired foetal signal (otherwise the wanted signal would be cancelled too).

Step 4 – give the practical choice: A chest lead capturing the maternal ECG alone is an ideal reference.

Why the other options are wrong:

- A, clean foetal ECG: is the very thing being sought, not available.
- B, unrelated white noise: carries no information about the interference.
- C, identical to the primary: would cancel signal and noise alike.

Final Answer: correlated with the noise, not the signal $\Rightarrow$ D

Answer: (D) Go Back to Q26

Q27.

Solution

Concept – the LMS weight-update rule: LMS performs steepest descent using the instantaneous squared error as its cost.

Step 1 – write the update: $\mathbf{w}(n+1) = \mathbf{w}(n) + \mu\, e(n)\, \mathbf{x}(n)$.

Step 2 – identify the correction term: The change in the weights is $\mu\, e(n)\, \mathbf{x}(n)$, the step size times the error times the input vector.

Step 3 – interpret it: Larger error or larger input drives a larger weight adjustment, and the correction vanishes as the error goes to zero.

Why the other options are wrong:

- B, second derivative: belongs to Newton-type methods, not LMS.
- C, integral of output: is not part of the LMS rule.
- D, fixed constant: would never converge to the optimum.

Final Answer: $\propto e(n)\, \mathbf{x}(n) \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q27

Q28.

Solution

Concept – the step-size trade-off in LMS: The step size μ sets both how fast the filter learns and how noisy its final solution is.

Step 1 – effect on convergence speed: A larger μ makes bigger corrections each step, so the weights approach the optimum faster.

Step 2 – effect on steady-state error: The same larger corrections make the weights jitter more about the optimum, raising the steady-state error (misadjustment).

Step 3 – state the trade-off: Thus a larger μ speeds convergence but worsens the steady-state accuracy.

Step 4 – note the stability bound: This holds only while μ stays within $0 < \mu < 2/\lambda_{\max}$; beyond that the filter diverges.

Why the other options are wrong:

- A, no effect: contradicts the role of μ.
- B, always unstable: is true only above the stability bound.
- D, slower with lower misadjustment: describes *decreasing* μ, the opposite.

Final Answer: faster convergence, larger misadjustment $\Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q28

Q29.

Solution

Concept – adaptive cancellation of a single tone: Feeding a sinusoidal reference lets the canceller remove just that frequency.

Step 1 – describe the converged filter: With a 60 Hz reference, the adaptive filter learns the amplitude and phase of the 60 Hz component in the primary channel.

Step 2 – describe the subtraction: It reconstructs that 60 Hz component and subtracts it, driving the output at 60 Hz to nearly zero.

Step 3 – describe the effect at other frequencies: Frequencies away from 60 Hz are uncorrelated with the reference, so they pass through essentially untouched.

Step 4 – name the equivalent response: A response that deeply attenuates one narrow frequency while passing the rest is a notch (band-reject) filter at 60 Hz.

Why the other options are wrong:

- A, all-pass: would not remove the 60 Hz interference.
- C and D, low-/high-pass: reject a whole band, not a single narrow line.

Final Answer: a 60 Hz notch filter $\Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q29

Q30.

Solution

Concept – SNR gain from ensemble averaging: Averaging N trials keeps the repeatable signal but averages down the uncorrelated noise, improving amplitude SNR by $\sqrt{N}$.

Step 1 – list the data: $N = 100$ trials.

Step 2 – write the improvement factor: Factor $= \sqrt{N}$.

Step 3 – substitute: $\sqrt{100}$

Step 4 – evaluate: $\sqrt{100} = 10$.

Step 5 – interpret: Averaging 100 trials makes the evoked response stand out 10 times more strongly above the noise.

Why the other options are wrong:

- A, 100: is N itself (the power-SNR gain), not the amplitude gain.
- B, 50: has no basis.
- D, 1000: is $N^{3/2}$, not $\sqrt{N}$.

Final Answer: improvement $= 10 \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q30

Q31.

Solution

Concept – Larmor resonance frequency: Protons precess at $f = \gamma B$, where $\gamma = 42.58$ MHz/T for hydrogen.

Step 1 – list the data: $\gamma = 42.58$ MHz/T, $B = 1.5$ T.

Step 2 – write the relation: $f = \gamma B$

Step 3 – substitute: $f = 42.58 \times 1.5$

Step 4 – multiply: $f = 63.87$ MHz

Step 5 – round: $f \approx 64$ MHz

Why the other options are wrong:

- B, 128 MHz: is the value at 3 T, not 1.5 T.
- C, 21 MHz: would correspond to about 0.5 T.
- D, 300 MHz: is far above the 1.5 T proton frequency.

Final Answer: $f \approx 64$ MHz $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q31

Q32.

Solution

Concept – the two MRI relaxation times: After the RF pulse, the magnetization relaxes along two independent routes, each with its own time constant.

Step 1 – define longitudinal relaxation: The regrowth of magnetization along the main field (the z-axis) is spin–lattice relaxation.

Step 2 – name its time constant: This recovery is governed by T_1.

Step 3 – contrast with transverse relaxation: The decay of the in-plane magnetization is spin–spin relaxation, described by T_2; TR and TE are operator-set timing parameters, not tissue relaxation times.

Why the other options are wrong:

- A, T_2: is transverse (spin–spin) relaxation.
- B and C, TE/TR: are sequence timing settings chosen by the operator.

Final Answer: longitudinal recovery is $T_1 \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q32

Q33.

Solution

Concept – exponential T_2 decay: The transverse magnetization falls as $M_{xy} = M_0 e^{-t/T_2}$; after one time constant it reaches $1/e$ of its start.

Step 1 – write the $1/e$ condition: Set $M_{xy} = M_0/e$, so $e^{-t/T_2} = e^{-1}$.

Step 2 – match the exponents: $\dfrac{t}{T_2} = 1$.

Step 3 – solve for t: $t = T_2$.

Step 4 – substitute the value: $t = 80$ ms.

Why the other options are wrong:

- A, 40 ms: is $T_2/2$, where the signal is still above $1/e$.
- C, 160 ms: is $2T_2$, where it has fallen to $1/e^2$.
- D, 8 ms: is $T_2/10$, far too early.

Final Answer: $t = 80$ ms $\Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q33

Q34.

Solution

Concept – how TR and TE set MRI image contrast: Short and long timing values emphasise different relaxation processes.

Step 1 – effect of a short TR: A short repetition time does not let tissues fully recover their longitudinal magnetization, so differences in T_1 dominate the signal.

Step 2 – effect of a short TE: A short echo time samples the signal before much T_2 decay, suppressing T_2 influence.

Step 3 – combine the two: Short TR with short TE therefore produces T_1-weighted contrast.

Why the other options are wrong:

- A, T_2-weighted: needs long TR and long TE.
- C, proton-density-weighted: needs long TR and short TE.
- D, diffusion-weighted: needs dedicated diffusion-gradient sequences.

Final Answer: T_1-weighted $\Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q34

Q35.

Solution

Concept – spatial encoding in MRI: The resonance frequency depends on the local field, so deliberately varying the field with position encodes location.

Step 1 – recall the Larmor dependence: Since $f = \gamma B$, making B vary with position makes f vary with position.

Step 2 – introduce the gradients: Gradient coils add small, linearly varying fields along x, y and z.

Step 3 – describe the encoding: These gradients provide slice selection, frequency encoding and phase encoding, which together localise the signal in three dimensions.

Why the other options are wrong:

- A, stronger static field only: a uniform field carries no position information.
- B, RF shields: only block external interference.
- C, higher proton density: affects signal strength, not spatial encoding.

Final Answer: magnetic field gradient coils $\Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q35

Q36.

Solution

Concept – corrosion of dissimilar metals: Two different metals in a shared electrolyte form a galvanic cell.

Step 1 – set up the cell: The two metals have different electrode potentials, and body fluid is the electrolyte that connects them.

Step 2 – identify the driven reaction: The more active (less noble) metal becomes the anode and corrodes faster, while the nobler metal is protected as the cathode.

Step 3 – name the process: This accelerated attack at the junction of two dissimilar metals is galvanic (bimetallic) corrosion.

Step 4 – give the design lesson: It is avoided by using matched metals or by electrically insulating dissimilar components.

Why the other options are wrong:

- B, elastic deformation: is a mechanical, reversible response, not corrosion.
- C, work hardening: is strengthening by plastic deformation.
- D, annealing: is a heat treatment.

Final Answer: galvanic (bimetallic) corrosion $\Rightarrow$ $\boxed{A}$

Answer: (A) Go Back to Q36

Q37.

Solution

Concept – passivation of implant metals: Some metals protect themselves by forming a stable oxide skin.

Step 1 – describe the layer: Titanium grows a TiO_2 film and 316L steel grows a chromium-rich oxide film, each only nanometres thick.

Step 2 – state its key properties: The film is dense, tightly adherent and, if scratched, re-forms almost instantly in the presence of oxygen.

Step 3 – link to corrosion resistance: This passive oxide film isolates the metal from body fluid, so corrosion is very slow.

Why the other options are wrong:

- A, polymer coating: is not spontaneously grown by the metal.
- B, rust flakes: are loose and non-protective, the opposite of passivation.
- C, calcium phosphate: may deposit biologically but is not the metal's own protective film.

Final Answer: a passive metal-oxide film $\Rightarrow$ D

Answer: (D) Go Back to Q37

Q38.

Solution

Concept – Hooke's law: In the elastic range, strain equals stress divided by Young's modulus: $\varepsilon = \sigma/E$.

Step 1 – list the data in base units: $\sigma = 55$ MPa $= 55 \times 10^6$ Pa, $E = 110$ GPa $= 110 \times 10^9$ Pa.

Step 2 – write the relation: $\varepsilon = \dfrac{\sigma}{E}$

Step 3 – substitute: $\varepsilon = \dfrac{55 \times 10^6}{110 \times 10^9}$

Step 4 – divide the coefficients: $\dfrac{55}{110} = 0.5$

Step 5 – combine the powers of ten: $\dfrac{10^6}{10^9} = 10^{-3}$

Step 6 – assemble: $\varepsilon = 0.5 \times 10^{-3} = 0.0005$

Final Answer: $\varepsilon = 0.0005 \Rightarrow$ B

Answer: (B) Go Back to Q38

Q39.

Solution

Concept – load sharing between implant and bone: Load follows the stiffer of two parallel load paths.

Step 1 – compare the stiffnesses: A metal stem has a much higher Young's modulus than the surrounding bone.

Step 2 – deduce the load path: Being far stiffer, the implant carries most of the applied load, leaving the adjacent bone under-loaded.

Step 3 – apply Wolff's law: Bone remodels to the stress it feels; an under-loaded region resorbs and loses density.

Step 4 – name the phenomenon: This unloading-driven bone loss beside a stiff implant is stress shielding.

Why the other options are wrong:

- A, osseointegration: is the desirable direct bonding of bone to implant.
- C, galvanic corrosion: is an electrochemical, not mechanical, effect.
- D, creep rupture: is slow deformation under sustained load, not bone resorption.

Final Answer: stress shielding $\Rightarrow$ $\boxed{B}$

Answer: (B) Go Back to Q39

Q40.

Solution

Concept – bioactive coatings: A bioactive material bonds directly with living bone rather than merely sitting beside it.

Step 1 – recall the composition of bone mineral: Natural bone mineral is a calcium-phosphate close to hydroxyapatite.

Step 2 – match the coating: Coating an implant with hydroxyapatite presents a surface chemically like bone, which osteoblasts readily attach to.

Step 3 – state the benefit: This encourages direct bone bonding and faster fixation of the implant.

Why the other options are wrong:

- B, silicone rubber: is a soft, bioinert elastomer, not bone-bonding.
- C, polyethylene: is a bearing polymer, chemically unlike bone.
- D, mild steel: corrodes and is not a bioactive coating.

Final Answer: hydroxyapatite $\Rightarrow$ $\boxed{A}$

Answer: (A) Go Back to Q40

Q41.

Solution

Concept – moment of a force: The moment (torque) about a pivot is the force times its perpendicular distance: $M = F \times d$.

Step 1 – list the data in base units: $F = 800$ N, $d = 4$ cm $= 0.04$ m.

Step 2 – write the relation: $M = F \times d$

Step 3 – substitute: $M = 800 \times 0.04$

Step 4 – multiply: $M = 32\ \text{N} \cdot \text{m}$

Step 5 – check the units: newton times metre gives newton-metre, the unit of moment.

Why the other options are wrong:

- A, 3.2 N·m: uses $d = 4$ mm instead of 4 cm.
- B, 320 N·m: keeps the distance in centimetres ($800 \times 4/10$ error).
- C, 3200 N·m: multiplies by 4 without converting from cm.

Final Answer: $M = 32\ \text{N} \cdot \text{m} \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q41

Q42.

Solution

Concept – poles are the roots of the characteristic equation: The closed-loop poles are the values of s that make the characteristic polynomial zero.

Step 1 – write the equation: $s^2 + 5s + 6 = 0$.

Step 2 – factorise: Find two numbers that multiply to 6 and add to 5: they are 2 and 3.

$s^2 + 5s + 6 = (s + 2)(s + 3)$

Step 3 – set each factor to zero: $s + 2 = 0 \Rightarrow s = -2$

$s + 3 = 0 \Rightarrow s = -3$

Step 4 – interpret: Both poles are real and negative, so the system is stable and overdamped, matching the crosses at -2 and -3 on the s-plane.

Why the other options are wrong:

- A, $+2, +3$: are the roots of $s^2 - 5s + 6$, an unstable system.
- B, $\pm j2.45$: would need a purely $s^2 + 6$ form (no damping term).

- D, $-1, -6$: multiply to 6 but add to 7, not 5.

Final Answer: $s = -2$ and $s = -3 \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q42

Q43.

Solution

Concept – phase of a first-order low-pass system: For $H(j\omega) = \dfrac{1}{1 + j\omega/\omega_c}$, the phase is $\phi = -\tan^{-1}(\omega/\omega_c)$.

Step 1 – evaluate at the corner frequency: Set $\omega = \omega_c$, so $\omega/\omega_c = 1$.

Step 2 – substitute into the phase expression: $\phi = -\tan^{-1}(1)$

Step 3 – evaluate the arctangent: $\tan^{-1}(1) = 45°$

Step 4 – apply the sign: $\phi = -45°$

Step 5 – cross-check with magnitude: At the same corner the magnitude is down 3 dB, the familiar pairing with the $-45°$ phase.

Why the other options are wrong:

- B, $0°$: is the low-frequency asymptote ($\omega \ll \omega_c$).
- C, $-90°$: is the high-frequency asymptote ($\omega \gg \omega_c$).
- D, $-180°$: needs a second-order (two-pole) system.

Final Answer: $\phi = -45° \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q43

Q44.

Solution

Concept – final-value theorem: The steady-state value is $y(\infty) = \lim_{s\to 0} s\,Y(s)$, valid when the system is stable.

Step 1 – write the transform: $Y(s) = \dfrac{4}{s(s+2)}$.

Step 2 – multiply by s: $s\,Y(s) = \dfrac{4}{s+2}$

Step 3 – take the limit as $s \to 0$: $y(\infty) = \dfrac{4}{0+2}$

Step 4 – evaluate: $y(\infty) = \dfrac{4}{2} = 2$

Step 5 – check applicability: The only pole besides the input pole is at $s = -2$ (left half-plane), so the theorem applies.

Why the other options are wrong:

- A, 4: forgets to divide by the $(s+2)$ factor at $s = 0$.
- B, 0: would require the numerator to vanish.
- D, 1: halves the correct value.

Final Answer: $y(\infty) = 2 \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q44

Q45.

Solution

Concept – Routh–Hurwitz stability test: A system is stable if and only if every entry in the first column of the Routh array is positive (no sign change).

Step 1 – write the coefficients: For $s^3 + 3s^2 + 3s + 1$: the coefficients are $1, 3, 3, 1$.

Step 2 – build the first two rows: s^3 row: 1 3

s^2 row: 3 1

Step 3 – compute the s^1 entry: $\dfrac{(3)(3) - (1)(1)}{3} = \dfrac{9-1}{3} = \dfrac{8}{3} \approx 2.67$

Step 4 – compute the s^0 entry: It is the last coefficient, 1.

Step 5 – inspect the first column: $1,\ 3,\ \frac{8}{3},\ 1$ are all positive, with no sign change.

Step 6 – conclude: All three poles lie in the left half-plane, so the system is stable.

Final Answer: stable (all poles in LHP) $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q45

Q46.

Solution

Concept – the isolation amplifier and patient safety: Patient safety demands that no fault current can flow from the mains into the patient through the electrodes.

Step 1 – identify the hazard: The recorder is mains-powered, so a fault could place a dangerous voltage on the input side.

Step 2 – describe the isolation barrier: An isolation amplifier passes the signal across a barrier (optical, capacitive or transformer coupled) with no direct wire connecting the two sides.

Step 3 – state the protection: Because there is no galvanic (metallic) path, mains fault current cannot reach the patient; only the wanted signal crosses the barrier.

Step 4 – note the added benefit: The barrier also blocks large common-mode voltages, improving safety and signal quality together.

Why the other options are wrong:

- A, amplify small signals: is the job of the instrumentation amplifier, not the isolation stage.
- C, filter interference: is done by filters, not by isolation.
- D, raise sampling rate: is unrelated to patient isolation.

Final Answer: it breaks the galvanic path to the patient $\Rightarrow \boxed{B}$

Answer: (B) Go Back to Q46

Answer Key

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