GATE Biomedical Engineering

Sample Paper – 4

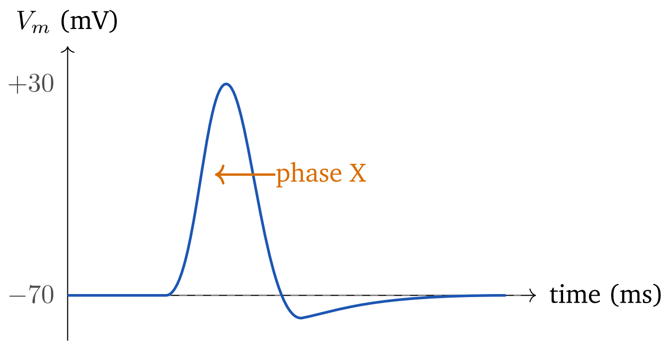
Duration: 128 Minutes **Maximum Marks: 72**

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. The neuronal action-potential trace below is marked at the steep upstroke labelled **phase X**. The rapid depolarisation during phase X is produced mainly by the inward movement of: **[1 mark]**



(A) Na^+ ions (sodium influx)

(B) K^+ ions (potassium efflux)

(C) Cl^- ions (chloride influx)

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

Q2. Immediately after a neuron fires, there is a brief interval during which no second action potential can be triggered however strong the stimulus. This interval is the: **[1 mark]**

(A) relative refractory period

(B) absolute refractory period

(C) latent period

(D) accommodation period

Q3. The fast, energy-efficient propagation of a nerve impulse in which the excitation appears to jump from one node of Ranvier to the next is known as saltatory conduction. It occurs in: **[1 mark]**

(A) unmyelinated axons only

(B) dendrites of the cell body

(C) cardiac muscle fibres

(D) myelinated axons

Q4. Under normal resting conditions, the pH of healthy human arterial blood is tightly regulated and is nearest to: **[1 mark]**

(A) 7.0

(B) 6.8

(C) 8.0

(D) 7.4

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

(A) dopamine

(B) noradrenaline

(C) acetylcholine

(D) gamma-aminobutyric acid (GABA)

Q6. A patient has a systolic blood pressure of 120 mmHg and a diastolic pressure of 90 mmHg. Using $\text{MAP} = \text{DBP} + \frac{1}{3}(\text{SBP} - \text{DBP})$, the mean arterial pressure is: **[1 mark]**

(A) 120 mmHg

(B) 90 mmHg

(C) 105 mmHg

(D) 100 mmHg

Electric Circuits, Signals and Systems

Q7. In the Laplace (s-domain) analysis of linear circuits, the impedance of an ideal inductor of inductance L is: **[1 mark]**

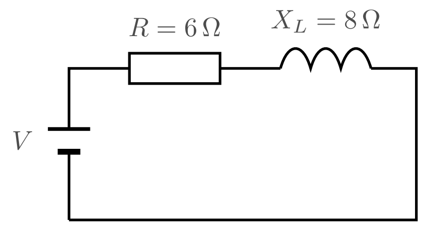
(A) $\dfrac{1}{sL}$

(B) sL

(C) $\dfrac{1}{sC}$

(D) R

Q8. In the series RL circuit shown, the resistance is $R = 6\ \Omega$ and the inductive reactance at the operating frequency is $X_L = 8\ \Omega$. The magnitude of the total impedance seen by the source is: **[1 mark]**



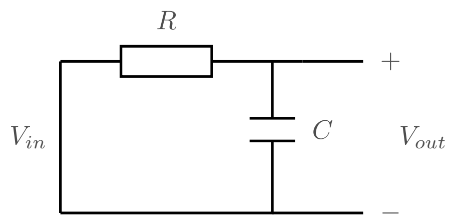
(A) $10\ \Omega$

(B) $2\ \Omega$

(C) $14\ \Omega$

(D) $7\ \Omega$

Q9. The first-order RC low-pass filter shown has $R = 16$ kΩ and $C = 100$ nF. Its -3 dB cut-off frequency $f_c = \dfrac{1}{2\pi RC}$ is nearest to: **[1 mark]**



(A) 1000 Hz

(B) 500 Hz

(C) 159 Hz

(D) 100 Hz

Q10. The Laplace transform of the unit-step function $u(t)$ (defined as $u(t) = 1$ for $t \geq 0$ and 0 otherwise) is: **[1 mark]**

(A) 1

(B) $\dfrac{1}{s}$

(C) $\dfrac{1}{s^2}$

(D) s

Q11. A first-order system has the transfer function $H(s) = \dfrac{5}{s+2}$. In the complex s-plane, the single pole of this system is located at: **[1 mark]**

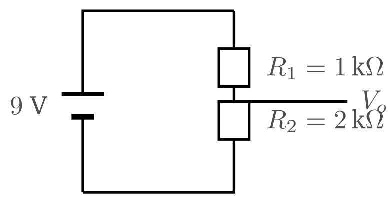
(A) $s = +2$

(B) $s = 0$

(C) $s = +5$

(D) $s = -2$

Q12. In the resistive voltage divider shown, a 9 V source is applied across $R_1 = 1$ kΩ in series with $R_2 = 2$ kΩ. The output voltage V_o taken across R_2 is: **[1 mark]**



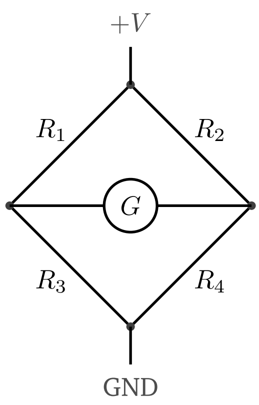
(A) 6 V

(B) 3 V

(C) 9 V

(D) 4.5 V

Q13. The Wheatstone bridge shown is balanced (the galvanometer G reads zero). The arms are $R_1 = 200\ \Omega$, $R_2 = 400\ \Omega$ and $R_3 = 250\ \Omega$. Using the balance condition $\frac{R_1}{R_3} = \frac{R_2}{R_4}$, the value of R_4 required for balance is: **[1 mark]**



(A) $125\ \Omega$

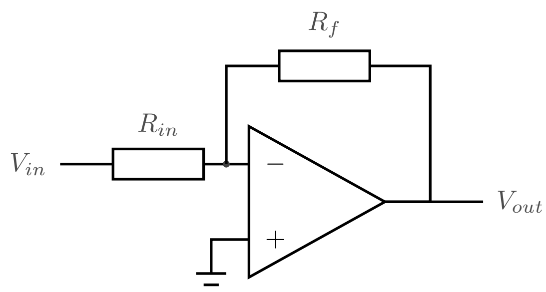
(B) $300\ \Omega$

(C) $500\ \Omega$

(D) $250\ \Omega$

Analog and Digital Electronics

Q14. For the ideal inverting operational-amplifier stage shown, $R_{in} = 20$ kΩ and $R_f = 40$ kΩ. The closed-loop voltage gain V_{out}/V_{in} is: **[1 mark]**



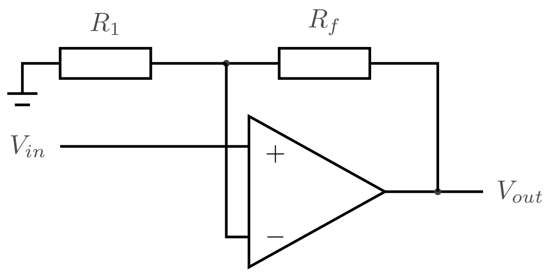
(A) $+2$

(B) $+3$

(C) -3

(D) -2

Q15. For the ideal non-inverting operational-amplifier stage shown, $R_1 = 10$ kΩ (to ground) and $R_f = 40$ kΩ (feedback). The closed-loop voltage gain V_{out}/V_{in} is: **[1 mark]**



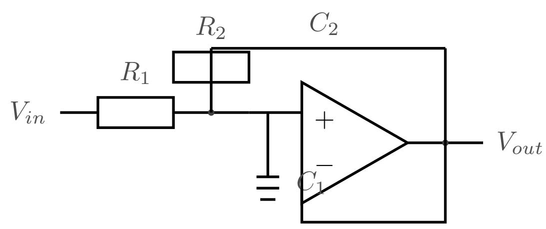
(A) 5

(B) 4

(C) -5

(D) -4

Q16. The op-amp stage shown uses two resistors and two capacitors arranged in the classic single-op-amp Sallen–Key topology. This topology is most commonly used to build a: **[1 mark]**



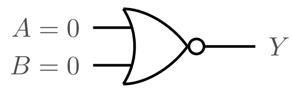
(A) second-order active filter

(B) precision full-wave rectifier

(C) logarithmic amplifier

(D) current mirror

Q17. For the two-input NOR gate shown, both inputs are held LOW, i.e. $A = 0$ and $B = 0$. The logic level at the output Y is: **[1 mark]**



(A) 0

(B) 1

(C) high impedance

(D) undefined

Q18. An analog-to-digital converter (ADC) uses 10 bits to represent each sample. The number of distinct output (quantization) levels it can produce is: **[1 mark]**

(A) 512

(B) 1024

(C) 2048

(D) 100

Q19. A 12-bit ADC digitises an input over a full-scale range of 0 to 4.096 V. Taking the number of steps as 2^{12}, the resolution (voltage per least-significant bit) of the converter is: **[1 mark]**

(A) 5 mV

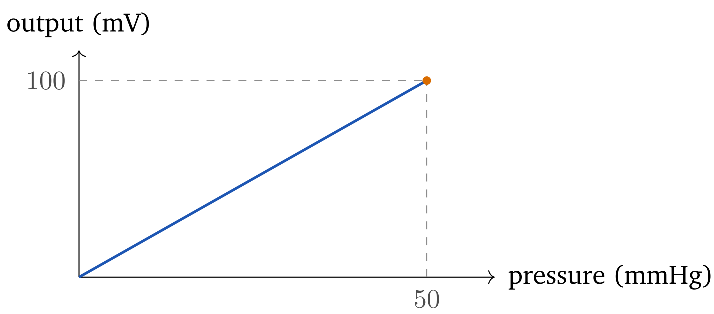
(B) 2 mV

(C) 4 mV

(D) 1 mV

Sensors, Bioinstrumentation and Measurements

Q20. The linear transfer characteristic of a blood-pressure transducer is sketched below: the output rises from 0 mV at 0 mmHg to 100 mV at 50 mmHg. The sensitivity (slope) of this transducer is: **[1 mark]**



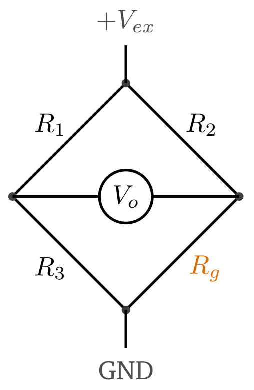
(A) 0.5 mV/mmHg

(B) 5 mV/mmHg

(C) 2 mV/mmHg

(D) 20 mV/mmHg

Q21. A metal-foil strain gauge of gauge factor 2.0 and unstrained resistance $350\ \Omega$ is bonded to a specimen and forms one arm of the bridge shown. When the specimen is loaded, the gauge experiences a longitudinal strain of $2000\ \mu\varepsilon$ ($\varepsilon = 2 \times 10^{-3}$). The change in the gauge resistance ΔR is: **[2 marks]**



(A) $1.4\ \Omega$

(B) $0.7\ \Omega$

(C) $2.8\ \Omega$

(D) $0.14\ \Omega$

Q22. A quarter-bridge strain-gauge circuit uses the same gauge (gauge factor 2.0, strain $2000\ \mu\varepsilon$) as above and a bridge excitation voltage of $V_{ex} = 5$ V. For small unbalance, the bridge output is $V_o = \frac{V_{ex}}{4} \cdot \frac{\Delta R}{R}$. The output voltage is: **[2 marks]**

(A) 10 mV

(B) 2.5 mV

(C) 5 mV

(D) 1 mV

Q23. A biopotential (instrumentation) amplifier has a differential-mode gain of $A_d = 2000$ and a common-mode gain of $A_c = 0.02$. Its common-mode rejection ratio expressed in decibels, $\mathrm{CMRR_{dB}} = 20\log_{10}(A_d/A_c)$, is: **[2 marks]**

(A) 60 dB

(B) 80 dB

(C) 100 dB

(D) 120 dB

Q24. An electromagnetic blood flowmeter measures the volume flow of blood through a vessel placed in a transverse magnetic field. The voltage it senses across the vessel is generated according to: **[2 marks]**

(A) the Doppler shift of a reflected ultrasound beam

(B) Faraday's law of electromagnetic induction

(C) the thermal-dilution principle

(D) the piezoelectric effect

Q25. In an invasive (catheter-based) arterial blood-pressure monitoring system, the sensing element most commonly converts the fluid pressure into an electrical signal by using a: **[2 marks]**

(A) flexible diaphragm bonded to a resistive strain-gauge bridge

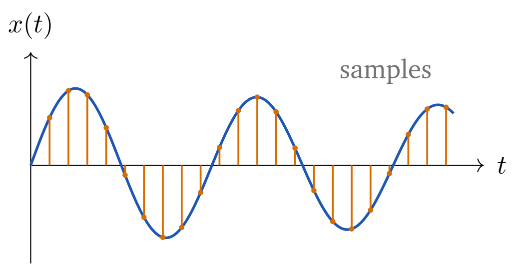
(B) thermocouple junction pair

(C) photodiode illuminated through the artery

(D) rotating turbine flow wheel

Biomedical Signal Processing

Q26. The continuous band-limited surface-EMG signal shown is to be digitised. Its highest significant frequency component is 1000 Hz. To avoid aliasing, the minimum (Nyquist) sampling frequency required is: **[2 marks]**



(A) 2000 Hz

(B) 1000 Hz

(C) 500 Hz

(D) 4000 Hz

Q27. A pure sinusoid of frequency 700 Hz is sampled at a rate of 1000 samples per second, which is below the Nyquist rate. The apparent (alias) frequency observed in the sampled signal is: **[2 marks]**

(A) 700 Hz

(B) 300 Hz

(C) 200 Hz

(D) 500 Hz

Q28. To quantify the amplitude (intensity) of a surface-EMG burst, a standard processing chain first full-wave rectifies the raw signal and then computes its: **[2 marks]**

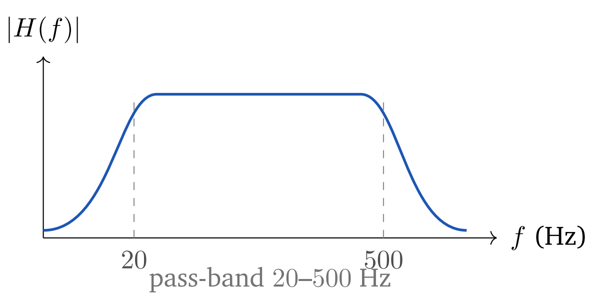
(A) DC offset only

(B) instantaneous phase

(C) zero-crossing count only

(D) root-mean-square (RMS) value

Q29. The energy of a surface-EMG signal is concentrated mainly in the band 20–500 Hz. To retain the EMG while removing low-frequency baseline drift and high-frequency noise, the appropriate filter has the magnitude response shown, which is that of a: **[2 marks]**



(A) low-pass filter with cut-off 10 Hz

(B) band-pass filter with pass-band 20–500 Hz

(C) high-pass filter with cut-off 1 kHz

(D) notch filter centred at 500 Hz

Q30. A recorded biosignal has a signal amplitude of 1 V (RMS) and a noise amplitude of 0.001 V (RMS). The signal-to-noise ratio expressed in decibels, $\text{SNR}_{\text{dB}} = 20 \log_{10}(V_s/V_n)$, is: **[2 marks]**

(A) 20 dB

(B) 40 dB

(C) 60 dB

(D) 80 dB

Medical Imaging Systems

Q31. In A-mode (amplitude-mode) diagnostic ultrasound, a single transducer sends a pulse and displays the returning echoes as spikes on a one-dimensional trace. The horizontal axis of this A-mode trace represents: **[2 marks]**

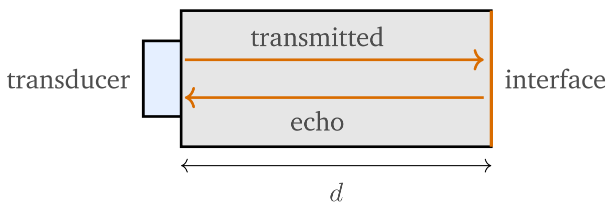
(A) depth of the reflecting interface (from the echo return time)

(B) the acoustic frequency of the transducer

(C) the scanning angle of the transducer

(D) the X-ray attenuation of the tissue

Q32. In the pulse-echo ultrasound arrangement shown, a transmitted pulse is reflected from an interface and the echo returns to the transducer after 130 μs. Taking the speed of sound in soft tissue as 1540 m/s, the depth of the interface ($d = \frac{1}{2}c\,t$) is nearest to: **[2 marks]**



(A) 20 cm

(B) 10 cm

(C) 5 cm

(D) 0.1 cm

Q33. For diagnostic ultrasound, the acoustic (characteristic) impedance of a medium is $Z = \rho c$. For cortical bone with density $\rho = 1900$ kg/m^3 and speed of sound $c = 4080$ m/s, the acoustic impedance is nearest to: **[2 marks]**

(A) $7.75 \times 10^3\ \mathrm{kg\,m^{-2}s^{-1}}$

(B) $7.75 \times 10^9\ \mathrm{kg\,m^{-2}s^{-1}}$

(C) $7.75 \times 10^6\ \mathrm{kg\,m^{-2}s^{-1}}$

(D) $7750\ \mathrm{kg\,m^{-2}s^{-1}}$

Q34. Compared with A-mode, B-mode (brightness-mode) ultrasound sweeps the beam across a plane and codes each echo as a bright dot whose brightness is proportional to echo strength. The clinical output of B-mode is: **[2 marks]**

(A) a single depth-versus-amplitude trace

(B) a two-dimensional grayscale cross-sectional image

(C) only a blood-velocity spectrum

(D) a three-dimensional bone-density map

Q35. An ultrasound beam travelling through soft tissue is almost totally reflected when it reaches a soft-tissue/air boundary (for example, at a gas-filled lung or bowel). The principal reason is that at this boundary: **[2 marks]**

(A) air chemically absorbs all the sound energy

(B) soft tissue is optically opaque to the beam

(C) the acoustic impedance mismatch between tissue and air is very large

(D) the two media have identical acoustic frequencies

Biomechanics and Biomaterials

Q36. A viscoelastic biological tissue such as tendon or ligament, when held under a constant applied stress, shows a slow continued increase of strain with time. This time-dependent behaviour is called: **[2 marks]**

(A) yielding

(B) mechanical resonance

(C) fatigue

(D) creep

Q37. Whole blood is a non-Newtonian fluid whose apparent viscosity decreases as the shear rate increases (shear thinning). The main microscopic reason for this behaviour is that: **[2 marks]**

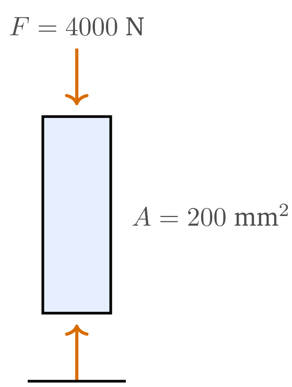
(A) the plasma freezes at high shear rate

(B) the viscosity of blood is in fact constant

(C) red blood cells aggregate into rouleaux at low shear and deform and align at high shear

(D) blood behaves as an ideal Newtonian fluid

Q38. The short bone segment shown has a uniform cross-sectional area of 200 mm^2 and carries a purely axial compressive load of 4000 N. The average normal (axial) stress in the segment is: **[2 marks]**



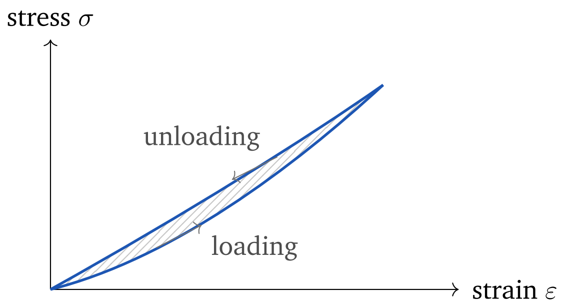
(A) 2 MPa

(B) 200 MPa

(C) 20 MPa

(D) 0.2 MPa

Q39. When a viscoelastic tissue is cyclically loaded and then unloaded, the loading and unloading stress–strain paths do not coincide, forming the closed loop shown. The area enclosed by this hysteresis loop represents: **[2 marks]**



(A) Young's modulus of the tissue

(B) the yield stress of the tissue

(C) Poisson's ratio of the tissue

(D) the energy dissipated per unit volume per cycle (hysteresis loss)

Q40. Which bioinert ceramic is most widely used for the hard, low-friction articulating (bearing) surfaces of hip and knee prostheses, chosen for its high hardness and excellent wear resistance? **[2 marks]**

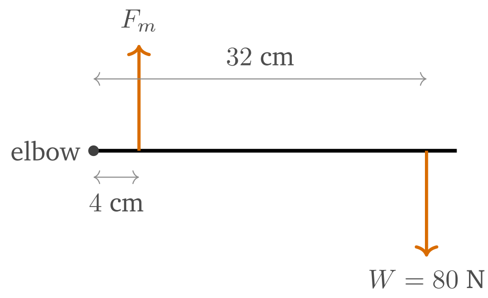
(A) alumina (Al_2O_3)

(B) mild (carbon) steel

(C) poly(vinyl chloride) (PVC)

(D) copper

Q41. The forearm is modelled as a lever pivoted at the elbow, as shown. A weight $W = 80$ N is held in the hand at a horizontal distance of 32 cm from the elbow, and the biceps muscle force F_m acts vertically upward at 4 cm from the elbow. Taking moments about the elbow for static equilibrium, the muscle force F_m is: **[2 marks]**



(A) 640 N

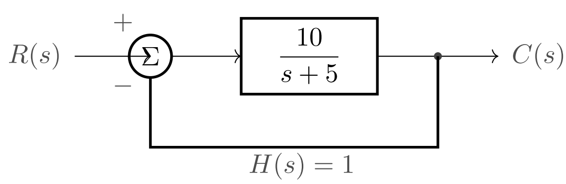
(B) 320 N

(C) 80 N

(D) 2560 N

Control Systems and Medical Instrumentation

Q42. For the unity-feedback control system shown, the forward-path transfer function is $G(s) = \dfrac{10}{s+5}$ and the feedback is unity ($H(s) = 1$). The closed-loop DC gain, i.e. the value of $\dfrac{C(s)}{R(s)}$ evaluated at $s = 0$, is: **[2 marks]**



(A) 1

(B) 2

(C) 0.5

(D) 0.667

Q43. A first-order system (for example a single-pole physiological sensor) has the transfer function $\dfrac{Y(s)}{X(s)} = \dfrac{1}{0.5\,s+1}$. The time constant of this system is: **[2 marks]**

(A) 0.5 s

(B) 1 s

(C) 2 s

(D) 0.25 s

Q44. A standard second-order system has the closed-loop transfer function $\frac{C(s)}{R(s)} = \frac{25}{s^2 + 6s + 25}$, of the form $\frac{\omega_n^2}{s^2 + 2\zeta\omega_n s + \omega_n^2}$. The undamped natural frequency ω_n of this system is: **[2 marks]**

(A) 25 rad/s

(B) 3 rad/s

(C) 5 rad/s

(D) 6 rad/s

Q45. A second-order system has the closed-loop transfer function $\frac{16}{s^2 + 4s + 16}$, of the form $\frac{\omega_n^2}{s^2 + 2\zeta\omega_n s + \omega_n^2}$. The damping ratio ζ of this system is: **[2 marks]**

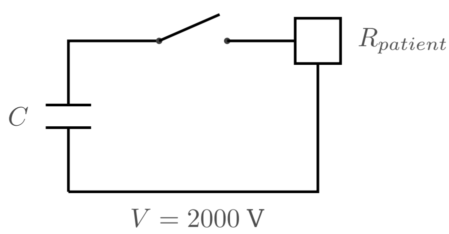
(A) 0.25

(B) 0.5

(C) 1

(D) 2

Q46. The defibrillator shown stores energy in a capacitor $C = 100\ \mu$F charged to $V = 2000$ V and then discharges it through the patient. The energy stored (and delivered), $E = \frac{1}{2}CV^2$, is: **[2 marks]**



(A) 100 J

(B) 200 J

(C) 400 J

(D) 50 J

Detailed Solutions

Q1.

Solution

Concept – ionic basis of the action-potential upstroke: The membrane potential of an excitable cell is set by the movement of ions through voltage-gated channels.

Step 1 – identify phase X on the trace: Phase X is the steep rising edge, where V_m climbs rapidly from about -70 mV towards $+30$ mV.

Step 2 – recall which channels open first: When the membrane reaches threshold, the fast voltage-gated Na^+ channels open.

Step 3 – direction of the ion flow: Na^+ is far more concentrated outside the cell, so it rushes inward down its electrochemical gradient.

Step 4 – effect on the potential: This inward positive current makes the inside of the cell rapidly less negative, producing the sharp depolarising upstroke.

Why the other options are wrong:

- B, K^+ efflux: drives the later repolarising (falling) phase, not the upstroke.
- C, Cl^- influx: contributes to inhibition/hyperpolarisation, not the spike.
- D, Ca^{2+} efflux: is not the mechanism of the neuronal upstroke.

Final Answer: sodium (Na^+) influx $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q1

Q2.

Solution

Concept – refractoriness after an action potential: Just after a spike the Na^+ channels are inactivated and cannot reopen for a short time.

Step 1 – define the interval in question: The question asks for the interval when *no* stimulus, however strong, can trigger a second spike.

Step 2 – match it to the correct term: That interval is the absolute refractory period, during which the fast Na^+ channels remain inactivated.

Step 3 – distinguish from the relative period: Later, during the relative refractory period, a stronger-than-normal stimulus *can* fire the cell.

Why the other options are wrong:

- A, relative refractory period: a strong stimulus can still fire the cell, so it does not match.

- C, latent period: is the delay before a response begins, not a block of excitability.
- D, accommodation: is the rise of threshold under a slowly increasing stimulus.

Final Answer: absolute refractory period $\Rightarrow \boxed{B}$

Answer: (B) Go Back to Q2

Q3.

Solution

Concept – saltatory conduction and myelin: Myelin is an insulating sheath interrupted by nodes of Ranvier.

Step 1 – recall where the membrane is excitable: Voltage-gated Na^+ channels are clustered only at the nodes of Ranvier.

Step 2 – describe the propagation: The impulse is regenerated node to node, appearing to jump across the insulated internodes.

Step 3 – identify the fibre type: This jumping (saltatory) conduction can occur only where a myelin sheath is present, i.e. in myelinated axons.

Why the other options are wrong:

- A, unmyelinated axons: conduct continuously and slowly, not by jumps.
- B, dendrites: chiefly conduct graded potentials, not saltatory spikes.
- C, cardiac muscle: spreads excitation cell to cell through gap junctions, a different mechanism.

Final Answer: myelinated axons $\Rightarrow \boxed{D}$

Answer: (D) Go Back to Q3

Q4.

Solution

Concept – acid–base balance of blood: Arterial blood pH is held in a very narrow range by buffers, the lungs and the kidneys.

Step 1 – recall the normal set-point: Healthy arterial blood pH is about 7.4 (normal range roughly 7.35–7.45).

Step 2 – interpret the value: A pH of 7.4 is slightly alkaline relative to neutral water (7.0).

Step 3 – note the clinical limits: Values below 7.35 indicate acidosis and above 7.45 indicate alkalosis.

Why the other options are wrong:

- A, 7.0: is neutral water, below the physiological set-point.
- B, 6.8: would be severe, life-threatening acidosis.
- C, 8.0: would be severe alkalosis, far outside the survivable range.

Final Answer: arterial blood pH $\approx 7.4 \Rightarrow \boxed{\text{D}}$

$\boxed{\text{Answer: (D)}}$ Go Back to Q4

Q5.

Solution

Concept – neuromuscular transmission: Skeletal muscle is driven by a somatic motor neuron across the neuromuscular junction.

Step 1 – recall the transmitter used there: The motor neuron releases acetylcholine (ACh) into the synaptic cleft.

Step 2 – describe its action: ACh binds nicotinic receptors on the muscle end-plate, opening cation channels and depolarising the fibre.

Step 3 – link to contraction: The resulting end-plate potential triggers a muscle action potential and contraction.

Why the other options are wrong:

- A, dopamine: acts in central pathways, not at the skeletal end-plate.
- B, noradrenaline: is a sympathetic transmitter, not the skeletal-muscle activator.
- D, GABA: is the main inhibitory transmitter in the central nervous system.

Final Answer: acetylcholine $\Rightarrow \boxed{\text{C}}$

$\boxed{\text{Answer: (C)}}$ Go Back to Q5

Q6.

Solution

Concept – mean arterial pressure (MAP): MAP $= \text{DBP} + \frac{1}{3}(\text{SBP} - \text{DBP})$, because the heart spends more of each cycle in diastole.

Step 1 – list the data: SBP $= 120$ mmHg, DBP $= 90$ mmHg.

Step 2 – find the pulse pressure: SBP $-$ DBP $= 120 - 90 = 30$ mmHg.

Step 3 – take one-third of the pulse pressure: $\frac{1}{3} \times 30 = 10$ mmHg.

Step 4 – add to the diastolic pressure: MAP $= 90 + 10$

MAP $= 100$ mmHg.

Final Answer: MAP $= 100$ mmHg $\Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q6

Q7.

Solution

Concept – s-domain impedance of an inductor: For a linear inductor the time-domain relation $v = L\,\dfrac{di}{dt}$ transforms (with zero initial current) to $V(s) = sL\,I(s)$.

Step 1 – form the impedance: Impedance is defined as $Z(s) = \dfrac{V(s)}{I(s)}$.

Step 2 – substitute the transformed relation: $Z(s) = \dfrac{sL\,I(s)}{I(s)}$

Step 3 – simplify: $Z(s) = sL$.

Why the other options are wrong:

- A, $\dfrac{1}{sL}$: is the admittance of the inductor, not its impedance.
- C, $\dfrac{1}{sC}$: is the impedance of a capacitor.
- D, R: is the impedance of a resistor, independent of s.

Final Answer: $Z_L = sL \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q7

Q8.

Solution

Concept – impedance magnitude of a series RL circuit: $|Z| = \sqrt{R^2 + X_L^2}$.

Step 1 – list the data: $R = 6\ \Omega$, $X_L = 8\ \Omega$.

Step 2 – square each term: $R^2 = 6^2 = 36$

$X_L^2 = 8^2 = 64$

Step 3 – add: $R^2 + X_L^2 = 36 + 64 = 100$

Step 4 – take the square root: $|Z| = \sqrt{100}$

$|Z| = 10\ \Omega$

Final Answer: $|Z| = 10\ \Omega \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q8

Q9.

Solution

Concept – cut-off frequency of a first-order RC low-pass filter: $f_c = \dfrac{1}{2\pi RC}$.

Step 1 – list the data in base units: $R = 16\ \text{k}\Omega = 1.6 \times 10^4\ \Omega$, $C = 100\ \text{nF} = 1 \times 10^{-7}\ \text{F}$.

Step 2 – form the product RC: $RC = 1.6 \times 10^4 \times 1 \times 10^{-7}$

$RC = 1.6 \times 10^{-3}\ \text{s}$

Step 3 – multiply by 2π: $2\pi RC = 2\pi \times 1.6 \times 10^{-3}$

$2\pi RC \approx 1.005 \times 10^{-2}\ \text{s}$

Step 4 – take the reciprocal: $f_c = \dfrac{1}{1.005 \times 10^{-2}}$

$f_c \approx 99.5\ \text{Hz} \approx 100\ \text{Hz}$

Final Answer: $f_c \approx 100\ \text{Hz} \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q9

Q10.

Solution

Concept – Laplace transform of the unit step: By definition $\mathcal{L}\{f(t)\} = \displaystyle\int_0^\infty f(t)\, e^{-st}\, dt$.

Step 1 – substitute $f(t) = u(t) = 1$ **for** $t \geq 0$: $\mathcal{L}\{u(t)\} = \int_0^\infty 1 \cdot e^{-st}\,dt$

Step 2 – integrate: $\int_0^\infty e^{-st}\,dt = \left[-\frac{1}{s}e^{-st}\right]_0^\infty$

Step 3 – evaluate the limits (for $\mathrm{Re}(s) > 0$**):** At $t \to \infty$, $e^{-st} \to 0$; at $t = 0$, $e^{-st} = 1$.

$= -\frac{1}{s}(0) + \frac{1}{s}(1)$

Step 4 – simplify: $\mathcal{L}\{u(t)\} = \frac{1}{s}$

Why the other options are wrong:

- A, 1: is the transform of the unit impulse $\delta(t)$.
- C, $\frac{1}{s^2}$: is the transform of the unit ramp $t\,u(t)$.
- D, s: is the transform of the derivative operator, not the step.

Final Answer: $\mathcal{L}\{u(t)\} = \frac{1}{s} \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q10

Q11.

Solution

Concept – poles of a transfer function: The poles are the values of s that make the denominator of $H(s)$ zero.

Step 1 – write the denominator: For $H(s) = \frac{5}{s+2}$, the denominator is $s + 2$.

Step 2 – set it to zero: $s + 2 = 0$

Step 3 – solve for s: $s = -2$

Step 4 – interpret: The pole lies at $s = -2$, in the left half-plane, so the system is stable.

Why the other options are wrong:

- A, $s = +2$: has the wrong sign; that would be an unstable right-half-plane pole.
- B, $s = 0$: is not a root of $s + 2$.
- C, $s = +5$: confuses the numerator constant with a pole location.

Final Answer: pole at $s = -2 \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q11

Q12.

Solution

Concept – resistive voltage divider: $V_o = V_s \dfrac{R_2}{R_1 + R_2}$ (the output is taken across R_2).

Step 1 – list the data: $V_s = 9$ V, $R_1 = 1$ kΩ, $R_2 = 2$ kΩ.

Step 2 – add the series resistances: $R_1 + R_2 = 1 + 2 = 3$ kΩ

Step 3 – form the divider ratio: $\dfrac{R_2}{R_1 + R_2} = \dfrac{2}{3}$

Step 4 – multiply by the source voltage: $V_o = 9 \times \dfrac{2}{3}$

$V_o = 6$ V

Final Answer: $V_o = 6 \text{ V} \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q12

Q13.

Solution

Concept – balanced Wheatstone bridge: At balance the two arm ratios are equal: $\dfrac{R_1}{R_3} = \dfrac{R_2}{R_4}$.

Step 1 – list the data: $R_1 = 200\ \Omega$, $R_2 = 400\ \Omega$, $R_3 = 250\ \Omega$.

Step 2 – rearrange for R_4: $R_4 = \dfrac{R_2\, R_3}{R_1}$

Step 3 – substitute the values: $R_4 = \dfrac{400 \times 250}{200}$

Step 4 – evaluate the numerator: $400 \times 250 = 100000$

Step 5 – divide: $R_4 = \dfrac{100000}{200} = 500\ \Omega$

Final Answer: $R_4 = 500\ \Omega \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q13

Q14.

Solution

Concept – gain of an ideal inverting amplifier: $\dfrac{V_{out}}{V_{in}} = -\dfrac{R_f}{R_{in}}$.

Step 1 – list the data: $R_{in} = 20$ kΩ, $R_f = 40$ kΩ.

Step 2 – form the resistance ratio: $\dfrac{R_f}{R_{in}} = \dfrac{40}{20} = 2$

Step 3 – apply the inverting sign: $\frac{V_{out}}{V_{in}} = -2$

Why the other options are wrong:

- A and B $(+2, +3)$: have the wrong sign; an inverting stage always gives a negative gain.
- C, -3: uses the wrong resistance ratio.

Final Answer: gain $= -2 \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q14

Q15.

Solution

Concept – gain of an ideal non-inverting amplifier: $\frac{V_{out}}{V_{in}} = 1 + \frac{R_f}{R_1}$.

Step 1 – list the data: $R_1 = 10\ \text{k}\Omega$, $R_f = 40\ \text{k}\Omega$.

Step 2 – form the resistance ratio: $\frac{R_f}{R_1} = \frac{40}{10} = 4$

Step 3 – add one: $\frac{V_{out}}{V_{in}} = 1 + 4$

$= 5$

Why the other options are wrong:

- B, 4: forgets the "$+1$" term of the non-inverting formula.
- C and D $(-5, -4)$: have the wrong sign; a non-inverting stage gives a positive gain.

Final Answer: gain $= 5 \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q15

Q16.

Solution

Concept – the Sallen–Key topology: It is a single-op-amp active-filter cell built from two resistors and two capacitors around a non-inverting amplifier.

Step 1 – count the reactive elements: Two capacitors give two independent energy-storage elements, so the cell is second order.

Step 2 – recall its purpose: Depending on where the R's and C's are placed, one Sallen–Key stage realises a second-order low-pass, high-pass or band-pass response with a chosen Q.

Step 3 – name the function: The Sallen–Key cell is therefore a second-order active filter.

Why the other options are wrong:

- B, precision rectifier: uses diodes in the feedback path, not two R–C pairs.
- C, logarithmic amplifier: relies on a diode or transistor's exponential characteristic.
- D, current mirror: is a transistor bias circuit, not an op-amp filter.

Final Answer: second-order active filter $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q16

Q17.

Solution

Concept – the NOR gate: A NOR gate outputs 1 only when *all* its inputs are 0; any HIGH input forces the output to 0.

Step 1 – write the Boolean expression: $Y = \overline{A + B}$.

Step 2 – substitute the inputs: $A = 0$, $B = 0$, so $A + B = 0 + 0 = 0$.

Step 3 – apply the inversion: $Y = \overline{0} = 1$.

Why the other options are wrong:

- A, 0: would require at least one input to be HIGH.
- C, high impedance: is a tri-state condition, not a logic output of a NOR gate.
- D, undefined: the output is fully defined for valid logic inputs.

Final Answer: $Y = 1 \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q17

Q18.

Solution

Concept – number of levels of an n-bit converter: An n-bit code can represent 2^n distinct values.

Step 1 – read the resolution: Here $n = 10$ bits.

Step 2 – compute 2^n: $2^{10} = 1024$.

Step 3 – interpret: The converter can output 1024 distinct quantization levels.

Why the other options are wrong:

- A, 512: is 2^9 (a 9-bit converter).
- C, 2048: is 2^{11} (an 11-bit converter).
- D, 100: is not a power of two and does not match a 10-bit code.

Final Answer: 1024 levels $\Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q18

Q19.

Solution

Concept – ADC resolution (volts per LSB): resolution $= \dfrac{\text{full-scale range}}{2^n}$.

Step 1 – list the data: Full-scale range $= 4.096$ V, $n = 12$ bits.

Step 2 – compute the number of steps: $2^{12} = 4096$.

Step 3 – divide the range by the steps: resolution $= \dfrac{4.096}{4096}$ V

Step 4 – evaluate: $= 0.001$ V

$= 1$ mV

Final Answer: resolution $= 1$ mV $\Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q19

Q20.

Solution

Concept – sensitivity of a linear transducer: For a linear characteristic the sensitivity is the slope, sensitivity $= \dfrac{\Delta(\text{output})}{\Delta(\text{input})}$.

Step 1 – read two points from the line: At 0 mmHg the output is 0 mV; at 50

mmHg the output is 100 mV.

Step 2 – find the change in output: $\Delta(\text{output}) = 100 - 0 = 100$ mV.

Step 3 – find the change in input: $\Delta(\text{input}) = 50 - 0 = 50$ mmHg.

Step 4 – divide to get the slope: sensitivity $= \dfrac{100 \text{ mV}}{50 \text{ mmHg}}$

$= 2$ mV/mmHg

Final Answer: sensitivity $= 2$ mV/mmHg $\Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q20

Q21.

Solution

Concept – strain-gauge resistance change: The gauge factor is defined by GF $= \dfrac{\Delta R/R}{\varepsilon}$, so $\Delta R = \text{GF} \times R \times \varepsilon$.

Step 1 – list the data: GF $= 2.0$, $R = 350\ \Omega$, $\varepsilon = 2000\ \mu\varepsilon = 2 \times 10^{-3}$.

Step 2 – multiply gauge factor and strain: GF $\times \varepsilon = 2.0 \times 2 \times 10^{-3} = 4 \times 10^{-3}$

Step 3 – multiply by the resistance: $\Delta R = 350 \times 4 \times 10^{-3}$

Step 4 – evaluate: $\Delta R = 1.4\ \Omega$

Why the other options are wrong:

- B, $0.7\ \Omega$: drops the factor of two from the gauge factor.
- C, $2.8\ \Omega$: doubles the correct value.
- D, $0.14\ \Omega$: is off by a factor of ten in the strain.

Final Answer: $\Delta R = 1.4\ \Omega \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q21

Q22.

Solution

Concept – quarter-bridge output voltage: $V_o = \dfrac{V_{ex}}{4} \cdot \dfrac{\Delta R}{R}$, and $\dfrac{\Delta R}{R} = \text{GF} \times \varepsilon$.

Step 1 – find the fractional resistance change: $\dfrac{\Delta R}{R} = \text{GF} \times \varepsilon = 2.0 \times 2 \times 10^{-3} = 4 \times 10^{-3}$

Step 2 – list the excitation: $V_{ex} = 5$ V.

Step 3 – form the quarter factor: $\dfrac{V_{ex}}{4} = \dfrac{5}{4} = 1.25\ \text{V}$

Step 4 – multiply by the fractional change: $V_o = 1.25 \times 4 \times 10^{-3}$

Step 5 – evaluate: $V_o = 5 \times 10^{-3}\ \text{V} = 5\ \text{mV}$

Final Answer: $V_o = 5\ \text{mV} \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q22

Q23.

Solution

Concept – common-mode rejection ratio in decibels: $\text{CMRR}_{\text{dB}} = 20 \log_{10}\left(\dfrac{A_d}{A_c}\right)$.

Step 1 – list the data: $A_d = 2000,\ A_c = 0.02.$

Step 2 – form the ratio: $\dfrac{A_d}{A_c} = \dfrac{2000}{0.02}$

Step 3 – evaluate the ratio: $= 100000 = 10^5$

Step 4 – take the logarithm: $\log_{10}(10^5) = 5$

Step 5 – multiply by 20**:** $\text{CMRR}_{\text{dB}} = 20 \times 5 = 100\ \text{dB}$

Final Answer: $\text{CMRR} = 100\ \text{dB} \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q23

Q24.

Solution

Concept – the electromagnetic blood flowmeter: Blood is an electrical conductor; moving it through a magnetic field induces a voltage.

Step 1 – set up the geometry: A transverse magnetic field B is applied across a vessel of diameter d; blood moves with velocity v along the vessel.

Step 2 – apply the induction law: By Faraday's/motional-EMF law, the induced voltage across the vessel is $E = B\,d\,v$, mutually perpendicular to B and v.

Step 3 – relate to flow: Since v is proportional to volume flow for a fixed cross-section, the measured voltage indicates blood flow.

Why the other options are wrong:

- A, Doppler shift: is used by ultrasound flowmeters, not the electromagnetic type.
- C, thermal dilution: measures cardiac output from a temperature transient,

a different method.

- D, piezoelectric effect: generates the ultrasound pulses, not the electromagnetic signal.

Final Answer: Faraday's law of electromagnetic induction $\Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q24

Q25.

Solution

Concept – invasive blood-pressure transducer: A fluid-filled catheter couples arterial pressure to a sensing diaphragm.

Step 1 – describe the mechanical element: The pressure deflects a thin flexible diaphragm.

Step 2 – describe the transduction: Strain gauges bonded to the diaphragm change resistance in proportion to its deflection.

Step 3 – read out the signal: The gauges form a Wheatstone bridge whose unbalance voltage is proportional to the applied pressure.

Why the other options are wrong:

- B, thermocouple: senses temperature, not pressure.
- C, photodiode: senses light and is used in optical methods such as pulse oximetry.
- D, turbine wheel: measures flow rate, not static pressure.

Final Answer: diaphragm bonded to a resistive strain-gauge bridge $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q25

Q26.

Solution

Concept – the Nyquist sampling criterion: To reconstruct a band-limited signal, the sampling rate must be at least twice its highest frequency: $f_s \geq 2f_{max}$.

Step 1 – identify the highest frequency: $f_{max} = 1000$ Hz.

Step 2 – apply the Nyquist rule: $f_{s,\min} = 2 \times f_{max}$

Step 3 – substitute: $f_{s,\min} = 2 \times 1000$

Step 4 – evaluate: $f_{s,\min} = 2000$ Hz

Why the other options are wrong:

- B, 1000 Hz: equals f_{max} and would alias the signal.
- C, 500 Hz: is below f_{max} and badly undersamples.
- D, 4000 Hz: is valid but is not the *minimum* required rate.

Final Answer: $f_{s,\min} = 2000$ Hz $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q26

Q27.

Solution

Concept – aliasing of an undersampled sinusoid: When $f > f_s/2$, the apparent frequency is the distance to the nearest multiple of f_s: $f_a = |f - kf_s|$.

Step 1 – list the data: Signal $f = 700$ Hz, sampling rate $f_s = 1000$ Hz.

Step 2 – check the Nyquist limit: $f_s/2 = 500$ Hz, and $700 > 500$, so aliasing occurs.

Step 3 – take $k = 1$ (nearest multiple of f_s): $f_a = |f - f_s| = |700 - 1000|$

Step 4 – evaluate: $f_a = 300$ Hz

Step 5 – confirm it is below Nyquist: $300 < 500$ Hz, so 300 Hz is a valid alias.

Final Answer: alias frequency $= 300$ Hz $\Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q27

Q28.

Solution

Concept – surface-EMG amplitude estimation: The raw EMG is a zero-mean random signal, so its plain average is near zero and useless as an amplitude measure.

Step 1 – rectify the signal: Full-wave rectification makes every sample positive by taking $|x(t)|$.

Step 2 – form the amplitude estimate: Squaring, averaging over a window and taking the square root gives the root-mean-square (RMS) value.

Step 3 – interpret: The RMS is proportional to the signal power and tracks the strength of muscle activation.

Why the other options are wrong:

- A, DC offset: is deliberately removed as an artefact, not used as the amplitude.
- B, instantaneous phase: describes timing, not burst intensity.
- C, zero-crossing count: estimates frequency content, not amplitude.

Final Answer: root-mean-square (RMS) value $\Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q28

Q29.

Solution

Concept – matching a filter to the EMG spectrum: The useful EMG energy lies in a band; both lower and higher frequencies must be attenuated.

Step 1 – read the magnitude response: The gain is near zero below 20 Hz, flat between 20 and 500 Hz, and falls again above 500 Hz.

Step 2 – name that shape: A response that passes only an intermediate band is a band-pass filter.

Step 3 – state the band: Here the pass-band is 20–500 Hz, which matches the EMG energy while rejecting baseline drift and high-frequency noise.

Why the other options are wrong:

- A, low-pass at 10 Hz: would remove almost all of the EMG.
- C, high-pass at 1 kHz: would keep only noise above the EMG band.
- D, notch at 500 Hz: removes one narrow line, not the out-of-band content.

Final Answer: band-pass filter, 20–500 Hz $\Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q29

Q30.

Solution

Concept – signal-to-noise ratio in decibels (amplitude form): $\text{SNR}_{\text{dB}} = 20\log_{10}\left(\frac{V_s}{V_n}\right)$.

Step 1 – list the data: $V_s = 1$ V, $V_n = 0.001$ V.

Step 2 – form the ratio: $\dfrac{V_s}{V_n} = \dfrac{1}{0.001} = 1000 = 10^3$

Step 3 – take the logarithm: $\log_{10}(10^3) = 3$

Step 4 – multiply by 20**:** $\text{SNR}_{\text{dB}} = 20 \times 3 = 60$ dB

Final Answer: $\text{SNR} = 60 \text{ dB} \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q30

Q31.

Solution

Concept – the A-mode ultrasound display: A-mode plots echo amplitude against the time the echo takes to return.

Step 1 – link echo time to distance: Sound travels at a known speed in tissue, so the round-trip time maps directly to the depth of the reflecting interface, $d = \frac{1}{2}ct$.

Step 2 – read the horizontal axis: Because time and depth are proportional, the horizontal axis is calibrated as depth.

Step 3 – read the vertical axis (for context): The vertical axis shows the amplitude (strength) of each echo spike.

Why the other options are wrong:

- B, transducer frequency: is a fixed system parameter, not an axis of the trace.
- C, scanning angle: is the axis in sector/B-mode scanning, not A-mode.
- D, X-ray attenuation: belongs to CT, not ultrasound.

Final Answer: depth of the reflecting interface $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q31

Q32.

Solution

Concept – pulse-echo depth measurement: The pulse travels to the interface and back, so the depth is half the total path: $d = \frac{1}{2}ct$.

Step 1 – list the data: $c = 1540$ m/s, echo time $t = 130\ \mu\text{s} = 130 \times 10^{-6}$ s.

Step 2 – compute the total round-trip distance: $ct = 1540 \times 130 \times 10^{-6}$

$= 1540 \times 1.3 \times 10^{-4}$

$= 0.2002$ m

Step 3 – halve it (one-way depth): $d = \frac{1}{2} \times 0.2002$

$d = 0.1001$ m

Step 4 – convert to centimetres: $d \approx 10$ cm

Final Answer: $d \approx 10$ cm $\Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q32

Q33.

Solution

Concept – acoustic (characteristic) impedance: $Z = \rho\, c$, the product of density and speed of sound.

Step 1 – list the data: $\rho = 1900$ kg/m^3, $c = 4080$ m/s.

Step 2 – multiply the coefficients: $1900 \times 4080 = 7.752 \times 10^6$

Step 3 – attach the units: $Z = 7.75 \times 10^6$ kg m^{-2}s^{-1} (i.e. rayl).

Step 4 – sanity check: This is a few times larger than soft tissue ($\approx 1.6 \times 10^6$), as expected for dense bone.

Why the other options are wrong:

- A, 7.75×10^3 and D, 7750: are off by three orders of magnitude.
- B, 7.75×10^9: is three orders of magnitude too large.

Final Answer: $Z \approx 7.75 \times 10^6$ kg m^{-2}s^{-1} $\Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q33

Q34.

Solution

Concept – the B-mode ultrasound display: B-mode (brightness mode) turns each echo into a bright pixel whose intensity encodes echo strength.

Step 1 – describe the scan: The beam is swept over a plane; each scan line records echoes versus depth.

Step 2 – build the image: Stacking many brightness-coded scan lines side by side forms a two-dimensional map.

Step 3 – name the output: The result is a real-time two-dimensional grayscale cross-sectional image of the anatomy.

Why the other options are wrong:

- A, single depth-versus-amplitude trace: is A-mode.
- C, blood-velocity spectrum: is Doppler mode.
- D, 3-D bone-density map: is not what conventional B-mode produces.

Final Answer: two-dimensional grayscale cross-sectional image $\Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q34

Q35.

Solution

Concept – reflection at an acoustic boundary: The fraction of ultrasound reflected depends on the mismatch in acoustic impedance, through $R = \left(\frac{Z_2 - Z_1}{Z_2 + Z_1}\right)^2$.

Step 1 – compare the impedances: Soft tissue has $Z \approx 1.6 \times 10^6$ rayl, while air has $Z \approx 400$ rayl, roughly four thousand times smaller.

Step 2 – evaluate the mismatch: With $Z_1 \gg Z_2$, the ratio $\frac{Z_2 - Z_1}{Z_2 + Z_1}$ approaches -1, so $R \to 1$.

Step 3 – interpret: Almost all the energy is reflected at a tissue/air boundary, which is why a coupling gel is used to exclude air.

Why the other options are wrong:

- A, air absorbs the energy: the loss is due to reflection, not absorption.
- B, tissue is optically opaque: optical opacity is irrelevant to sound.
- D, identical frequencies: frequency is unchanged and is not the cause.

Final Answer: very large acoustic-impedance mismatch $\Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q35

Q36.

Solution

Concept – viscoelastic creep: Viscoelastic materials show time-dependent deformation because they combine elastic and viscous behaviour.

Step 1 – fix the loading condition: The stress is held *constant* over time.

Step 2 – observe the response: Under that constant stress the strain keeps increasing gradually with time.

Step 3 – name the phenomenon: Progressive strain at constant stress is called creep.

Why the other options are wrong:

- A, yielding: is the onset of permanent deformation at a stress level, not a time effect.
- B, resonance: is a dynamic vibration phenomenon.
- C, fatigue: is failure under many load cycles, not slow strain at constant load.

Note: the complementary effect, a fall of stress at constant strain, is called stress relaxation.

Final Answer: creep $\Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q36

Q37.

Solution

Concept – shear-thinning of blood: Blood's apparent viscosity falls as the shear rate rises, so it is non-Newtonian.

Step 1 – behaviour at low shear: At low shear rates red blood cells stick together into stacked aggregates called rouleaux, which raises the apparent viscosity.

Step 2 – behaviour at high shear: At high shear rates these aggregates break up and the flexible cells deform and align with the flow, lowering the viscosity.

Step 3 – conclude: This microscopic rearrangement of red cells makes blood shear-thinning.

Why the other options are wrong:

- A, plasma freezes: plasma does not freeze during flow; this is nonsense physically.
- B, viscosity is constant: that would make blood Newtonian, contradicting observation.
- D, ideal Newtonian fluid: blood is explicitly non-Newtonian.

Final Answer: red cells aggregate at low shear and align at high shear $\Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q37

Q38.

Solution

Concept – average axial (normal) stress: $\sigma = \dfrac{F}{A}$.

Step 1 – list the data in base units: $F = 4000$ N, $A = 200\ \text{mm}^2 = 200 \times 10^{-6}\ \text{m}^2 = 2 \times 10^{-4}\ \text{m}^2$.

Step 2 – substitute: $\sigma = \dfrac{4000}{2 \times 10^{-4}}$

Step 3 – divide the coefficients: $\dfrac{4000}{2} = 2000$

Step 4 – handle the power of ten: $\dfrac{1}{10^{-4}} = 10^4$, so $\sigma = 2000 \times 10^4$

Step 5 – assemble: $\sigma = 2 \times 10^7$ Pa $= 20$ MPa

Final Answer: $\sigma = 20$ MPa $\Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q38

Q39.

Solution

Concept – mechanical hysteresis in viscoelastic tissue: Because the material is viscous as well as elastic, the loading and unloading curves differ.

Step 1 – interpret the loop: The area under the loading curve is the work done on the tissue; the area under the unloading curve is the energy returned.

Step 2 – interpret the enclosed area: Their difference, the area *inside* the closed loop, is energy that is not recovered.

Step 3 – name it: This lost energy per unit volume per cycle is the hysteresis loss, dissipated mainly as heat.

Why the other options are wrong:

- A, Young's modulus: is the slope of the curve, not the enclosed area.
- B, yield stress: is a stress level, not an area.
- C, Poisson's ratio: relates lateral to axial strain and has no connection to the loop area.

Final Answer: energy dissipated per cycle (hysteresis loss) $\Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q39

Q40.

Solution

Concept – bioinert bearing ceramics: Articulating surfaces of joint implants need extreme hardness, low friction and wear resistance.

Step 1 – recall the standard material: Alumina (Al_2O_3) is a bioinert ceramic that is very hard and highly wear-resistant.

Step 2 – link property to use: Its hardness gives a smooth, low-wear articulating surface for ceramic femoral heads in hip prostheses.

Step 3 – confirm biocompatibility: Alumina is chemically stable and bioinert, provoking minimal tissue reaction.

Why the other options are wrong:

- B, mild steel: corrodes in the body and is not used as a bearing surface.
- C, PVC: is a soft polymer, unsuitable for a hard load-bearing joint surface.
- D, copper: is toxic to tissue and mechanically unsuitable.

Final Answer: alumina (Al_2O_3) $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q40

Q41.

Solution

Concept – static moment balance of the forearm lever: For equilibrium, the clockwise and anticlockwise moments about the elbow pivot must be equal.

Step 1 – list the data: $W = 80$ N at $d_W = 32$ cm; muscle force F_m at $d_m = 4$ cm.

Step 2 – write the moment balance about the elbow: $F_m \times d_m = W \times d_W$

Step 3 – solve for F_m: $F_m = \dfrac{W \times d_W}{d_m}$

Step 4 – substitute (the cm units cancel): $F_m = \dfrac{80 \times 32}{4}$

Step 5 – evaluate the numerator: $80 \times 32 = 2560$

Step 6 – divide: $F_m = \dfrac{2560}{4} = 640$ N

Final Answer: $F_m = 640$ N $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q41

Q42.

Solution

Concept – closed-loop transfer function and DC gain: For a unity-feedback loop, $\dfrac{C(s)}{R(s)} = \dfrac{G(s)}{1+G(s)}$; the DC gain is its value at $s = 0$.

Step 1 – write the forward gain: $G(s) = \dfrac{10}{s+5}$.

Step 2 – form the closed-loop transfer function: $\dfrac{C(s)}{R(s)} = \dfrac{\frac{10}{s+5}}{1+\frac{10}{s+5}}$

Step 3 – combine the denominator over a common denominator: $1 + \dfrac{10}{s+5} = \dfrac{s+5+10}{s+5} = \dfrac{s+15}{s+5}$

Step 4 – divide the two fractions: $\dfrac{C(s)}{R(s)} = \dfrac{10}{s+5} \times \dfrac{s+5}{s+15} = \dfrac{10}{s+15}$

Step 5 – evaluate at $s = 0$ for the DC gain: $\left.\dfrac{C}{R}\right|_{s=0} = \dfrac{10}{0+15} = \dfrac{10}{15}$ ≈ 0.667

Final Answer: DC gain $\approx 0.667 \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q42

Q43.

Solution

Concept – standard form of a first-order transfer function: $\dfrac{1}{\tau s+1}$, where τ is the time constant (the coefficient of s).

Step 1 – compare with the given function: $\dfrac{1}{0.5\,s+1}$ has the form $\dfrac{1}{\tau s+1}$ with the coefficient of s equal to 0.5.

Step 2 – read off the time constant: $\tau = 0.5$ s.

Step 3 – interpret: The step response reaches 63.2% of its final value after 0.5 s.

Why the other options are wrong:

- B, 1 s: ignores the coefficient of s.
- C, 2 s: is the reciprocal $1/\tau$ (the pole magnitude), not τ.
- D, 0.25 s: does not follow from the given coefficient.

Final Answer: $\tau = 0.5$ s $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q43

Q44.

Solution

Concept – standard second-order transfer function: $\dfrac{\omega_n^2}{s^2 + 2\zeta\omega_n s + \omega_n^2}$, so the constant term equals ω_n^2.

Step 1 – match the denominators: Given $s^2 + 6s + 25$, compare with $s^2 + 2\zeta\omega_n s + \omega_n^2$.

Step 2 – equate the constant terms: $\omega_n^2 = 25$

Step 3 – solve for ω_n: $\omega_n = \sqrt{25}$

$\omega_n = 5$ rad/s

Step 4 – (check) find ζ from the middle term: $2\zeta\omega_n = 6 \Rightarrow \zeta = \dfrac{6}{2 \times 5} = 0.6$, an underdamped system, consistent.

Why the other options are wrong:

- A, 25 rad/s: is ω_n^2, not ω_n.
- B, 3 rad/s: is the real part of the poles ($\zeta\omega_n$), not ω_n.
- D, 6 rad/s: is the coefficient $2\zeta\omega_n$, not ω_n.

Final Answer: $\omega_n = 5$ rad/s $\Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q44

Q45.

Solution

Concept – damping ratio from the standard second-order form: For $\dfrac{\omega_n^2}{s^2 + 2\zeta\omega_n s + \omega_n^2}$, the constant term gives ω_n and the middle term gives $2\zeta\omega_n$.

Step 1 – find ω_n from the constant term: $\omega_n^2 = 16 \Rightarrow \omega_n = 4$ rad/s.

Step 2 – read the middle coefficient: $2\zeta\omega_n = 4$.

Step 3 – substitute $\omega_n = 4$: $2\zeta(4) = 4$

$8\zeta = 4$

Step 4 – solve for ζ: $\zeta = \dfrac{4}{8} = 0.5$

Step 5 – interpret: Since $0 < \zeta < 1$, the response is underdamped.

Final Answer: $\zeta = 0.5 \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q45

Q46.

Solution

Concept – energy stored in a charged capacitor: $E = \frac{1}{2}CV^2$.

Step 1 – list the data in base units: $C = 100\ \mu\text{F} = 100 \times 10^{-6}\ \text{F} = 1 \times 10^{-4}\ \text{F}$, $V = 2000\ \text{V}$.

Step 2 – square the voltage: $V^2 = (2000)^2 = 4 \times 10^6\ \text{V}^2$

Step 3 – multiply by the capacitance: $CV^2 = 1 \times 10^{-4} \times 4 \times 10^6$

Step 4 – combine coefficients and powers of ten: $1 \times 4 = 4$ and $10^{-4} \times 10^6 = 10^2$, so $CV^2 = 4 \times 10^2 = 400$

Step 5 – apply the factor one-half: $E = \frac{1}{2} \times 400$

$E = 200\ \text{J}$

Final Answer: $E = 200\ \text{J} \Rightarrow \boxed{\text{B}}$

$\boxed{\textbf{Answer: (B)}}$ Go Back to Q46

Answer Key

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