GATE Biomedical Engineering

Sample Paper – 1

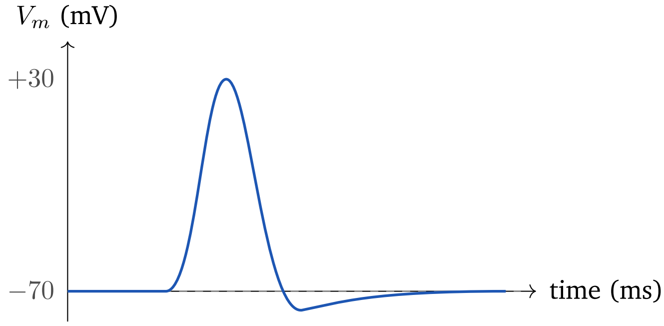
Duration: 128 Minutes **Maximum Marks: 72**

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 trace below shows the transmembrane potential of a typical resting neuron before an action potential is fired. The resting membrane potential indicated by the dashed baseline is nearest to: **[1 mark]**



(A) $+30$ mV

(B) 0 mV

(C) -90 mV

(D) -70 mV

Q2. In the normal human heart, the structure that spontaneously initiates the electrical impulse of each heartbeat and therefore acts as the natural pacemaker is the: **[1 mark]**

(A) sinoatrial (SA) node

(B) atrioventricular (AV) node

(C) bundle of His

(D) Purkinje fibres

Q3. A resting adult has a heart rate of 72 beats per minute and a stroke volume of about 70 mL per beat. The cardiac output is nearest to: **[1 mark]**

(A) 0.5 L/min

(B) 50 L/min

(C) 5 L/min

(D) 500 L/min

Q4. During quiet breathing, the volume of air moved in or out of the lungs with each normal breath (the tidal volume) of a healthy adult is nearest to: **[1 mark]**

(A) 1200 mL

(B) 500 mL

(C) 150 mL

(D) 4500 mL

Q5. The basic structural and functional unit of the kidney, responsible for filtering blood and forming urine, is the: **[1 mark]**

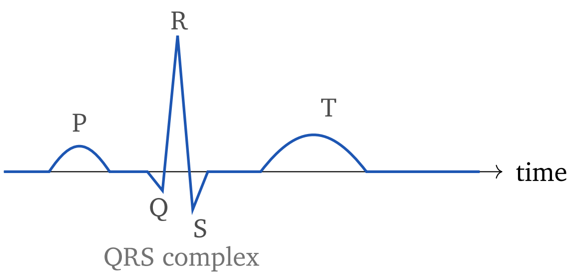
(A) nephron

(B) alveolus

(C) neuron

(D) sarcomere

Q6. The idealised single-beat electrocardiogram (ECG) waveform is shown below. The prominent **QRS complex** marked on the trace corresponds physiologically to: **[1 mark]**



(A) atrial depolarization

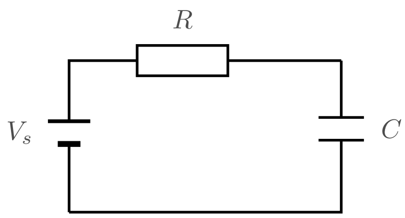
(B) ventricular repolarization

(C) atrial repolarization

(D) ventricular depolarization

Electric Circuits, Signals and Systems

Q7. For the series RC circuit shown, $R = 10$ kΩ and $C = 10$ μF. The time constant of the circuit is: **[1 mark]**



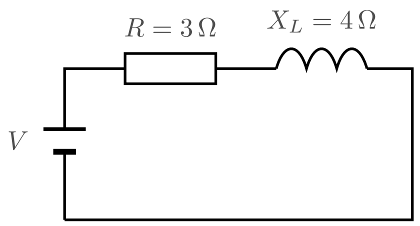
(A) 1 s

(B) 0.01 s

(C) 0.1 s

(D) 10 s

Q8. In the series RL circuit shown, the resistance is $R = 3\ \Omega$ and the inductive reactance at the operating frequency is $X_L = 4\ \Omega$. The magnitude of the total impedance seen by the source is: **[1 mark]**



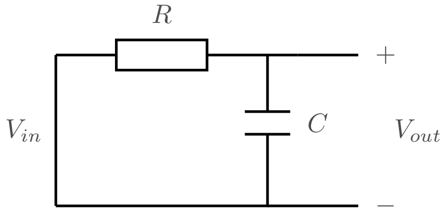
(A) $7\ \Omega$

(B) $1\ \Omega$

(C) $3.5\ \Omega$

(D) $5\ \Omega$

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



(A) 159 Hz

(B) 1000 Hz

(C) 100 Hz

(D) 15.9 Hz

Q10. In the Laplace (s-domain) analysis of linear circuits, the impedance of an ideal capacitor of capacitance C is: **[1 mark]**

(A) sC

(B) $\frac{1}{sC}$

(C) sL

(D) R

Q11. A continuous-time linear time-invariant (LTI) system described by a rational transfer function is bounded-input bounded-output (BIBO) stable if and only if: **[1 mark]**

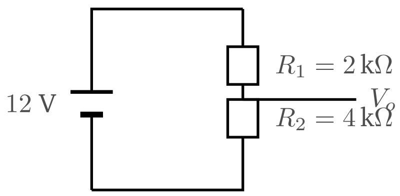
(A) all poles lie in the left half of the s-plane

(B) all poles lie in the right half of the s-plane

(C) at least one pole lies on the imaginary ($j\omega$) axis

(D) all zeros lie in the left half of the s-plane

Q12. In the resistive voltage divider shown, a 12 V source is applied across $R_1 = 2$ kΩ in series with $R_2 = 4$ kΩ. The output voltage V_o taken across R_2 is: **[1 mark]**



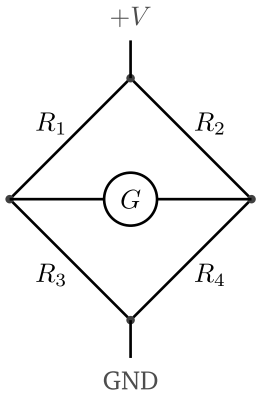
(A) 4 V

(B) 8 V

(C) 6 V

(D) 12 V

Q13. The Wheatstone bridge shown is balanced (the galvanometer G reads zero). The arms are $R_1 = 100\ \Omega$, $R_2 = 200\ \Omega$ and $R_3 = 150\ \Omega$. The value of R_4 required for balance is: **[1 mark]**



(A) $75\ \Omega$

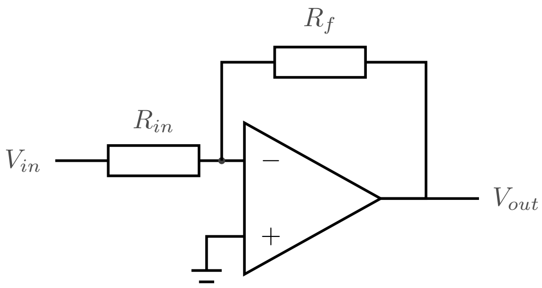
(B) $200\ \Omega$

(C) $300\ \Omega$

(D) $100\ \Omega$

Analog and Digital Electronics

Q14. For the ideal inverting operational-amplifier stage shown, $R_{in} = 10$ kΩ and $R_f = 100$ kΩ. The closed-loop voltage gain V_{out}/V_{in} is: **[1 mark]**



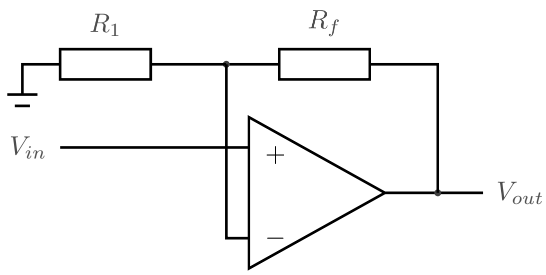
(A) $+10$

(B) $+11$

(C) -11

(D) -10

Q15. For the ideal non-inverting operational-amplifier stage shown, $R_1 = 10$ kΩ (to ground) and $R_f = 90$ kΩ (feedback). The closed-loop voltage gain V_{out}/V_{in} is: **[1 mark]**



(A) -9

(B) 9

(C) -10

(D) 10

Q16. Which of the following is a property of an *ideal* operational amplifier? **[1 mark]**

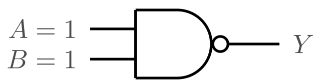
(A) zero input impedance

(B) finite open-loop gain

(C) infinite input impedance and zero output impedance

(D) infinite output impedance

Q17. For the two-input NAND gate shown, both inputs are held HIGH, i.e. $A = 1$ and $B = 1$. The logic level at the output Y is: **[1 mark]**



(A) 1

(B) high impedance

(C) 0

(D) undefined

Q18. An analog-to-digital converter (ADC) uses 8 bits to represent each sample. The number of distinct output (quantization) levels it can produce is: **[1 mark]**

(A) 128

(B) 256

(C) 512

(D) 8

Q19. An 8-bit ADC digitises an input over a full-scale range of 0 to 5 V. Taking the number of steps as 2^8, the resolution (voltage per least-significant bit) of the converter is nearest to: **[1 mark]**

(A) 19.5 mV

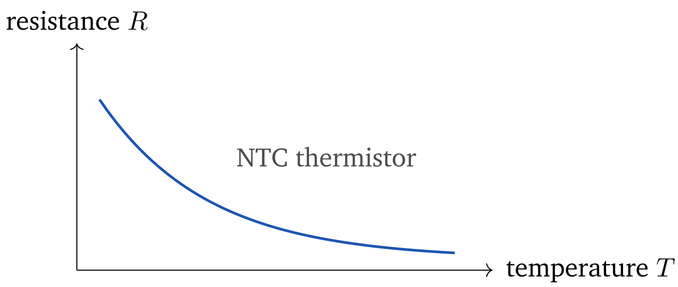
(B) 39 mV

(C) 625 mV

(D) 5 mV

Sensors, Bioinstrumentation and Measurements

Q20. The resistance–temperature characteristic sketched below is that of a common thermistor used in biomedical thermometry. From the curve, the thermistor is best described as a device whose resistance: **[1 mark]**



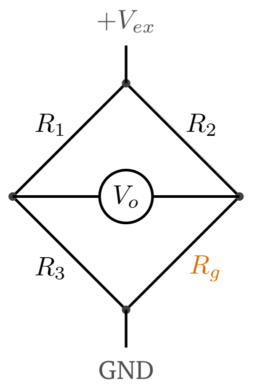
(A) increases linearly with temperature

(B) is essentially independent of temperature

(C) increases with the square of temperature

(D) decreases as temperature increases (negative temperature coefficient)

Q21. A metal-foil strain gauge of gauge factor 2.0 and unstrained resistance 120 Ω 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 1000 $\mu\varepsilon$ ($\varepsilon = 1 \times 10^{-3}$). The change in the gauge resistance ΔR is: **[2 marks]**



(A) $0.12\ \Omega$

(B) $2.4\ \Omega$

(C) $0.24\ \Omega$

(D) $0.024\ \Omega$

Q22. A quarter-bridge strain-gauge circuit uses the same gauge (gauge factor 2.0, strain $1000\ \mu\varepsilon$) as above and a bridge excitation voltage of $V_{ex} = 4$ 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) 4 mV

(B) 2 mV

(C) 8 mV

(D) 1 mV

Q23. A biopotential (instrumentation) amplifier has a differential-mode gain of $A_d = 1000$ and a common-mode gain of $A_c = 0.1$. Its common-mode rejection ratio expressed in decibels, $\text{CMRR}_{\text{dB}} = 20\log_{10}(A_d/A_c)$, is: **[2 marks]**

(A) 40 dB

(B) 80 dB

(C) 100 dB

(D) 60 dB

Q24. A Linear Variable Differential Transformer (LVDT) is a widely used displacement transducer in biomedical instrumentation. Its operation is based on the principle of: **[2 marks]**

(A) the piezoelectric effect

(B) a change of ohmic resistance with length

(C) a change of capacitance with plate spacing

(D) mutual inductance (electromagnetic induction) between coils

Q25. A thermocouple used for temperature measurement generates an EMF when its two junctions are held at different temperatures. This transduction is based on the: **[2 marks]**

(A) Peltier effect

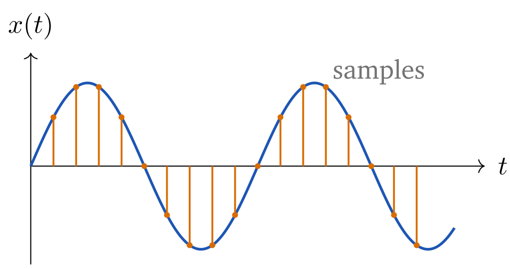
(B) piezoresistive effect

(C) Hall effect

(D) Seebeck effect

Biomedical Signal Processing

Q26. The continuous band-limited signal shown is to be digitised. Its highest significant frequency component is 500 Hz (typical of a surface EMG signal). To avoid aliasing, the minimum (Nyquist) sampling frequency required is: **[2 marks]**



(A) 1000 Hz

(B) 500 Hz

(C) 250 Hz

(D) 2000 Hz

Q27. A pure sinusoid of frequency 300 Hz is sampled at a rate of 500 samples per second, which is below the Nyquist rate. The apparent (alias) frequency observed in the sampled signal is: **[2 marks]**

(A) 300 Hz

(B) 200 Hz

(C) 100 Hz

(D) 250 Hz

Q28. A simple N-point moving-average filter is applied to a noisy biomedical signal. In the frequency domain this filter behaves as a: **[2 marks]**

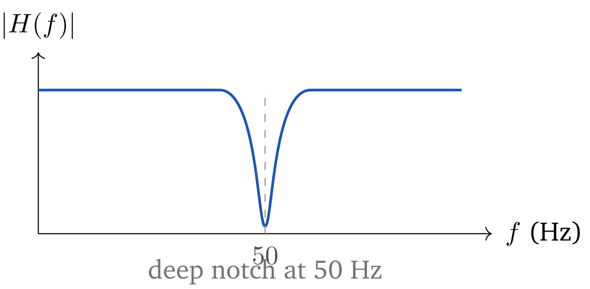
(A) high-pass filter

(B) band-pass filter

(C) low-pass filter

(D) all-pass filter

Q29. The magnitude response shown belongs to the filter most appropriate for removing narrow-band 50 Hz power-line interference from a recorded ECG while preserving the rest of the ECG spectrum. This filter is a: **[2 marks]**



(A) low-pass filter with cut-off 50 Hz

(B) high-pass filter

(C) pure differentiator

(D) notch (band-reject) filter centred at 50 Hz

Q30. A recorded biosignal has a signal amplitude of 1 V (RMS) and a noise amplitude of 0.01 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) 100 dB

(C) 10 dB

(D) 40 dB

Medical Imaging Systems

Q31. In X-ray computed tomography (CT), pixel values are expressed on the Hounsfield scale, which is calibrated using water and air as references. The Hounsfield unit (HU) value assigned to pure water is: **[2 marks]**

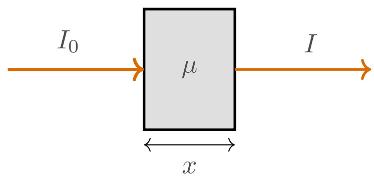
(A) 0 HU

(B) -1000 HU

(C) $+1000$ HU

(D) $+100$ HU

Q32. A monoenergetic X-ray beam of incident intensity I_0 passes through a slab of tissue of thickness x and linear attenuation coefficient μ, as shown, and follows $I = I_0 e^{-\mu x}$. If $\mu = 0.693$ cm^{-1} and $x = 1$ cm, the transmitted fraction I/I_0 is: **[2 marks]**



(A) 0.50 (about 50%)

(B) 0.37

(C) 0.693

(D) 0.25

Q33. For diagnostic ultrasound, the acoustic (characteristic) impedance of a medium is $Z = \rho c$. For soft tissue with density $\rho = 1000$ kg/m^3 and speed of sound $c = 1540$ m/s, the acoustic impedance is nearest to: **[2 marks]**

(A) $1.54 \times 10^3\ \mathrm{kg\,m^{-2}s^{-1}}$

(B) $1.54 \times 10^6\ \mathrm{kg\,m^{-2}s^{-1}}$

(C) $1.54 \times 10^9\ \mathrm{kg\,m^{-2}s^{-1}}$

(D) $1540\ \mathrm{kg\,m^{-2}s^{-1}}$

Q34. In diagnostic ultrasound imaging, the depth of a reflecting interface is computed from the pulse-echo time using an assumed average speed of sound in soft tissue. The value conventionally assumed is: **[2 marks]**

(A) 1540 m/s

(B) 340 m/s

(C) 3000 m/s

(D) 15400 m/s

Q35. Conventional clinical magnetic resonance imaging (MRI) forms its image chiefly by detecting the nuclear magnetic resonance signal from the nuclei of: **[2 marks]**

(A) carbon-13

(B) oxygen-16

(C) hydrogen (protons)

(D) sodium-23

Biomechanics and Biomaterials

Q36. The longitudinal (axial) Young's modulus of healthy adult human cortical (compact) bone is nearest to: **[2 marks]**

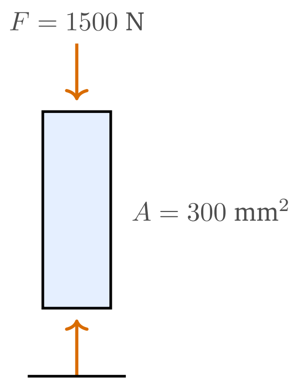
(A) 18 GPa

(B) 200 GPa

(C) 1.8 GPa

(D) 70 GPa

Q37. A short segment of bone with a uniform cross-sectional area of 300 mm^2 carries a purely axial compressive load of 1500 N, as shown. The average normal (axial) stress in the segment is: **[2 marks]**



(A) 5 MPa

(B) 50 MPa

(C) 0.5 MPa

(D) 450 MPa

Q38. A specimen of cortical bone (Young's modulus $E = 18$ GPa) is loaded so that the axial stress is $\sigma = 18$ MPa, within the linear-elastic range. The axial strain produced, $\varepsilon = \sigma/E$, is: **[2 marks]**

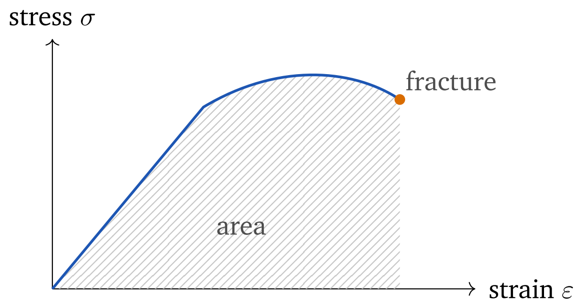
(A) 0.01

(B) 0.001

(C) 0.1

(D) 0.0001

Q39. The stress–strain curve of a biomaterial specimen loaded to fracture is shown, with the region under the curve shaded. The total area under the stress–strain curve up to fracture represents the material's: **[2 marks]**



(A) toughness (energy absorbed per unit volume)

(B) stiffness

(C) yield strength

(D) Poisson's ratio

Q40. Which material is most widely used for load-bearing orthopaedic implants such as hip-joint stems, chiefly because of its high strength-to-weight ratio, corrosion resistance and excellent biocompatibility? **[2 marks]**

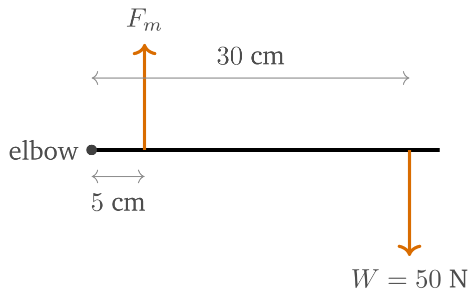
(A) copper

(B) titanium alloy (Ti–6Al–4V)

(C) mild (carbon) steel

(D) lead

Q41. The forearm is modelled as a lever pivoted at the elbow, as shown. A weight $W = 50$ N is held in the hand at a horizontal distance of 30 cm from the elbow, and the biceps muscle force F_m acts vertically upward at 5 cm from the elbow. Taking moments about the elbow for static equilibrium, the muscle force F_m is: **[2 marks]**



(A) 50 N

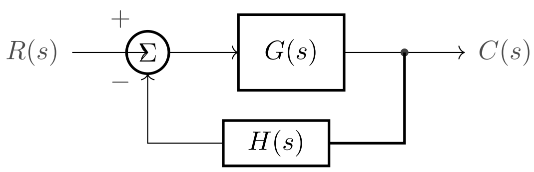
(B) 300 N

(C) 250 N

(D) 1500 N

Control Systems and Medical Instrumentation

Q42. For the single-loop negative-feedback control system shown, the forward-path transfer function is $G(s)$ and the feedback-path transfer function is $H(s)$. The overall closed-loop transfer function $C(s)/R(s)$ is: [2 marks]



(A) $\dfrac{G(s)}{1 - G(s)H(s)}$

(B) $\dfrac{G(s)H(s)}{1 + G(s)}$

(C) $G(s)\,H(s)$

(D) $\dfrac{G(s)}{1 + G(s)H(s)}$

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

(A) 0.5 s

(B) 1 s

(C) 2 s

(D) 4 s

Q44. A standard second-order control system has a damping ratio $\zeta = 1$. The nature of its transient response is: [2 marks]

(A) undamped (sustained oscillation)

(B) underdamped (decaying oscillation)

(C) critically damped (fastest non-oscillatory response)

(D) overdamped (sluggish, no oscillation)

Q45. A control system has the characteristic equation $s^3 + 2s^2 + 3s + 4 = 0$. The order of the system (equal to the number of closed-loop poles) is: **[2 marks]**

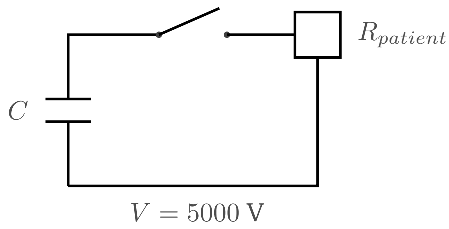
(A) 2

(B) 3

(C) 4

(D) 1

Q46. The defibrillator shown stores energy in a capacitor $C = 32\ \mu$F charged to $V = 5000$ V and then discharges it through the patient. The energy stored (and delivered), $E = \frac{1}{2}CV^2$, is: **[2 marks]**



(A) 200 J

(B) 800 J

(C) 400 J

(D) 100 J

Detailed Solutions

Q1.

Solution

Concept – resting membrane potential of an excitable cell: Before an action potential, an excitable cell (neuron or muscle fibre) sits at a steady negative trans-membrane potential set mainly by the K^+ gradient and the Na/K pump.

Step 1 – read the baseline of the trace: The dashed baseline before the spike is the resting level, labelled -70 mV.

Step 2 – recall the standard physiological value: For a typical mammalian neuron the resting membrane potential is about -70 mV (inside negative with respect to outside).

Step 3 – interpret the spike: The transient rise towards $+30$ mV is the depolarising overshoot of the action potential, not the resting value.

Why the other options are wrong:

- A, $+30$ mV: is the peak of the action potential, not the resting level.
- B, 0 mV: would mean no charge separation across the membrane.
- C, -90 mV: is closer to the resting potential of a cardiac ventricular cell, not a typical neuron.

Final Answer: resting potential ≈ -70 mV $\Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q1

Q2.

Solution

Concept – the cardiac conduction system has a natural pacemaker: Impulse generation begins at the fastest spontaneously depolarising tissue, which then drives the rest of the heart.

Step 1 – identify the site of automatic impulse generation: The sinoatrial (SA) node, in the wall of the right atrium, depolarises fastest and sets the heart rate.

Step 2 – trace the normal conduction pathway: SA node $\rightarrow$ AV node $\rightarrow$ bundle of His $\rightarrow$ bundle branches $\rightarrow$ Purkinje fibres.

Step 3 – pick the pacemaker: The first element in this chain, the SA node, is the natural pacemaker.

Why the other options are wrong:

- B, AV node: only paces if the SA node fails, and at a slower intrinsic rate.
- C and D, bundle of His / Purkinje fibres: are conduction pathways with even slower intrinsic rates.

Final Answer: sinoatrial (SA) node $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q2

Q3.

Solution

Concept – cardiac output relation: CO $=$ HR $\times$ SV, the volume of blood pumped per minute.

Step 1 – list the data: HR $= 72$ beats/min, SV $= 70$ mL/beat.

Step 2 – multiply: CO $= 72 \times 70$

CO $= 5040$ mL/min

Step 3 – convert to litres: CO $= \dfrac{5040}{1000}$ L/min

CO $= 5.04$ L/min ≈ 5 L/min

Final Answer: CO ≈ 5 L/min $\Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q3

Q4.

Solution

Concept – lung volumes at rest: Tidal volume is the air exchanged per normal quiet breath.

Step 1 – recall the standard value: For a healthy adult at rest the tidal volume is about 500 mL per breath.

Step 2 – distinguish it from the other volumes: Of that 500 mL, roughly 150 mL fills the conducting airways (anatomical dead space) and about 350 mL reaches the alveoli.

Why the other options are wrong:

- A, 1200 mL: is of the order of the residual volume.
- C, 150 mL: is the anatomical dead space, not the tidal volume.
- D, 4500 mL: is of the order of the vital capacity.

Final Answer: tidal volume ≈ 500 mL $\Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q4

Q5.

Solution

Concept – functional unit of an organ: The functional unit is the smallest structure that carries out the organ's characteristic task.

Step 1 – identify the kidney's task: The kidney filters blood and forms urine through millions of tiny filtering-and-reabsorbing units.

Step 2 – name that unit: Each such unit is a nephron (glomerulus plus its tubule).

Why the other options are wrong:

- B, alveolus: is the functional unit of the lung.
- C, neuron: is the functional unit of the nervous system.
- D, sarcomere: is the contractile unit of skeletal muscle.

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

Answer: (A) Go Back to Q5

Q6.

Solution

Concept – the ECG waves map to cardiac electrical events: Each deflection of the ECG corresponds to depolarisation or repolarisation of a chamber.

Step 1 – assign the P wave: The P wave is atrial depolarisation.

Step 2 – assign the QRS complex: The large, sharp QRS complex is ventricular depolarisation. Because the ventricular muscle mass is large, this deflection is the tallest.

Step 3 – assign the T wave: The T wave is ventricular repolarisation. Atrial repolarisation is hidden inside the QRS and is not separately visible.

Why the other options are wrong:

- A, atrial depolarization: is the P wave.
- B, ventricular repolarization: is the T wave.
- C, atrial repolarization: is masked by the QRS and has no distinct wave.

Final Answer: QRS = ventricular depolarization $\Rightarrow \boxed{D}$

Answer: (D) Go Back to Q6

Q7.

Solution

Concept – time constant of a series RC circuit: $\tau = RC$.

Step 1 – list the data in base units: $R = 10$ kΩ $= 10 \times 10^3$ Ω, $C = 10$ μF $= 10 \times 10^{-6}$ F.

Step 2 – substitute: $\tau = (10 \times 10^3)(10 \times 10^{-6})$

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: $\tau = 100 \times 10^{-3}$

$\tau = 0.1$ s

Final Answer: $\tau = 0.1$ s $\Rightarrow$ $\boxed{\text{C}}$

Answer: (C) 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: $R = 3$ Ω, $X_L = 4$ Ω.

Step 2 – square each term: $R^2 = 3^2 = 9$

$X_L^2 = 4^2 = 16$

Step 3 – add: $R^2 + X_L^2 = 9 + 16 = 25$

Step 4 – take the square root: $|Z| = \sqrt{25}$

$|Z| = 5$ Ω

Final Answer: $|Z| = 5$ Ω $\Rightarrow$ $\boxed{\text{D}}$

Answer: (D) 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: $R = 1\ \text{k}\Omega = 10^3\ \Omega$, $C = 1\ \mu\text{F} = 10^{-6}$ F.

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

$RC = 10^{-3}$ s

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

$2\pi RC = 6.283 \times 10^{-3}$

Step 4 – take the reciprocal: $f_c = \dfrac{1}{6.283 \times 10^{-3}}$

$f_c = 159.15$ Hz ≈ 159 Hz

Final Answer: $f_c \approx 159$ Hz $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q9

Q10.

Solution

Concept – s-domain impedance of a capacitor: From $i = C\dfrac{dv}{dt}$, the Laplace-domain relation is $I(s) = sC\,V(s)$, so $Z_C(s) = \dfrac{V(s)}{I(s)}$.

Step 1 – write the current–voltage law in the time domain: $i(t) = C\dfrac{dv}{dt}$

Step 2 – take the Laplace transform (zero initial condition): $I(s) = sC\,V(s)$

Step 3 – form the impedance: $Z_C(s) = \dfrac{V(s)}{I(s)} = \dfrac{1}{sC}$

Why the other options are wrong:

- A, sC: is the admittance of the capacitor, not its impedance.
- C, sL: is the impedance of an inductor.
- D, R: is the impedance of a resistor.

Final Answer: $Z_C = \dfrac{1}{sC} \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q10

Q11.

Solution

Concept – BIBO stability of an LTI system: A causal continuous-time LTI system is BIBO stable exactly when every pole of its transfer function has a negative real part.

Step 1 – state the pole-location condition: All poles must lie strictly in the left half of the s-plane ($\text{Re}\{s\} < 0$).

Step 2 – interpret physically: Left-half-plane poles give decaying natural responses, so a bounded input produces a bounded output.

Why the other options are wrong:

- B, poles in the right half: give growing responses, hence instability.
- C, a pole on the $j\omega$ axis: gives a marginally stable (non-decaying) mode, which fails strict BIBO stability.
- D, zeros in the left half: zeros do not determine stability; only poles do.

Final Answer: all poles in the left half s-plane $\Rightarrow$ $\boxed{\text{A}}$

Answer: (A) Go Back to Q11

Q12.

Solution

Concept – resistive voltage divider: For two resistors in series, the voltage across R_2 is $V_o = V\dfrac{R_2}{R_1 + R_2}$.

Step 1 – list the data: $V = 12$ V, $R_1 = 2$ kΩ, $R_2 = 4$ kΩ.

Step 2 – sum the resistances: $R_1 + R_2 = 2 + 4 = 6$ kΩ

Step 3 – form the divider ratio: $\dfrac{R_2}{R_1 + R_2} = \dfrac{4}{6} = \dfrac{2}{3}$

Step 4 – multiply by the source voltage: $V_o = 12 \times \dfrac{2}{3}$

$V_o = 8$ V

Final Answer: $V_o = 8$ V $\Rightarrow$ $\boxed{\text{B}}$

Answer: (B) Go Back to Q12

Q13.

Solution

Concept – Wheatstone bridge balance condition: The bridge is balanced when the products of opposite arms are equal: $R_1 R_4 = R_2 R_3$.

Step 1 – list the data: $R_1 = 100\ \Omega$, $R_2 = 200\ \Omega$, $R_3 = 150\ \Omega$.

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

Step 3 – substitute: $R_4 = \dfrac{200 \times 150}{100}$

Step 4 – evaluate the numerator: $200 \times 150 = 30000$

Step 5 – divide: $R_4 = \dfrac{30000}{100} = 300\ \Omega$

Final Answer: $R_4 = 300\ \Omega \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q13

Q14.

Solution

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

Step 1 – list the data: $R_{in} = 10\ \text{k}\Omega$, $R_f = 100\ \text{k}\Omega$.

Step 2 – form the resistor ratio: $\dfrac{R_f}{R_{in}} = \dfrac{100}{10} = 10$

Step 3 – apply the negative sign of the inverting configuration: $\dfrac{V_{out}}{V_{in}} = -10$

Why the other options are wrong:

- A, $+10$: drops the inversion; an inverting amplifier has a negative gain.
- B and C, ± 11: use $1 + R_f/R_{in}$, which is the *non-inverting* formula.

Final Answer: gain $= -10 \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q14

Q15.

Solution

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

Step 1 – list the data: $R_1 = 10\ \text{k}\Omega$, $R_f = 90\ \text{k}\Omega$.

Step 2 – form the resistor ratio: $\frac{R_f}{R_1} = \frac{90}{10} = 9$

Step 3 – add one: $\frac{V_{out}}{V_{in}} = 1 + 9$

$$\frac{V_{out}}{V_{in}} = 10$$

Why the other options are wrong:

- A and C, negative values: a non-inverting amplifier gives a positive gain.
- B, 9: uses R_f/R_1 alone and forgets the $+1$.

Final Answer: gain $= +10 \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q15

Q16.

Solution

Concept – idealisation of an operational amplifier: The ideal op-amp model assumes limiting values that make circuit analysis simple.

Step 1 – list the ideal properties: Infinite open-loop gain, infinite input impedance, zero output impedance, infinite bandwidth and zero input bias current.

Step 2 – match to the options: Only option C, "infinite input impedance and zero output impedance," states two of these correctly.

Why the other options are wrong:

- A, zero input impedance: an ideal op-amp draws no input current, so its input impedance is infinite, not zero.
- B, finite open-loop gain: the ideal gain is infinite.
- D, infinite output impedance: the ideal output impedance is zero.

Final Answer: infinite input impedance and zero output impedance $\Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q16

Q17.

Solution

Concept – NAND truth table: A NAND gate is an AND followed by inversion: $Y = \overline{A \cdot B}$.

Step 1 – form the AND of the inputs: $A \cdot B = 1 \cdot 1 = 1$

Step 2 – invert the result: $Y = \overline{1} = 0$

Step 3 – state the output level: The output Y is LOW, i.e. logic 0. (A NAND output is 0 only when all inputs are 1.)

Why the other options are wrong:

- A, 1: would be the output of an AND gate, not a NAND, for these inputs.
- B and D, high impedance / undefined: a NAND gate always drives a defined logic level.

Final Answer: $Y = 0 \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q17

Q18.

Solution

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

Step 1 – list the data: $n = 8$ bits.

Step 2 – compute 2^n: $2^8 = 256$

Step 3 – state the result: The ADC produces 256 distinct output levels (0 to 255).

Final Answer: 256 levels $\Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q18

Q19.

Solution

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

Step 1 – list the data: Full-scale range $= 5$ V, $n = 8$ bits.

Step 2 – compute the number of steps: $2^8 = 256$

Step 3 – divide the range by the steps: resolution $= \dfrac{5}{256}$

Step 4 – evaluate: resolution $= 0.01953$ V

Step 5 – convert to millivolts: $0.01953\text{ V} = 19.53\text{ mV} \approx 19.5\text{ mV}$

Final Answer: resolution $\approx 19.5\text{ mV} \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q19

Q20.

Solution

Concept – thermistor temperature coefficient: The most common biomedical thermistor is the NTC (negative temperature coefficient) type.

Step 1 – read the characteristic: The plotted curve falls steeply as temperature rises, so resistance decreases with increasing temperature.

Step 2 – name that behaviour: A falling R–T curve is a negative temperature coefficient (NTC).

Why the other options are wrong:

- A, linear rise: describes a metallic RTD, not the curved NTC characteristic shown.
- B, temperature-independent: would be a flat line, contradicting the plot.
- C, square-law rise: is neither the plotted shape nor a standard thermistor law.

Final Answer: resistance decreases as temperature increases (NTC) $\Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q20

Q21.

Solution

Concept – strain gauge relation: The gauge factor links fractional resistance change to strain: $\dfrac{\Delta R}{R} = \text{GF} \cdot \varepsilon$, so $\Delta R = \text{GF} \cdot \varepsilon \cdot R$.

Step 1 – list the data: $\text{GF} = 2.0$, $\varepsilon = 1000\ \mu\varepsilon = 1 \times 10^{-3}$, $R = 120\ \Omega$.

Step 2 – form the fractional change: $\dfrac{\Delta R}{R} = 2.0 \times 1 \times 10^{-3}$

$$\frac{\Delta R}{R} = 2 \times 10^{-3}$$

Step 3 – multiply by the resistance: $\Delta R = 2 \times 10^{-3} \times 120$

Step 4 – evaluate: $\Delta R = 0.24\ \Omega$

Final Answer: $\Delta R = 0.24\ \Omega \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q21

Q22.

Solution

Concept – output of a quarter-bridge: $V_o = \frac{V_{ex}}{4} \cdot \frac{\Delta R}{R}$, with $\frac{\Delta R}{R} = \text{GF} \cdot \varepsilon$.

Step 1 – compute the fractional resistance change: $\frac{\Delta R}{R} = \text{GF} \cdot \varepsilon = 2.0 \times 1 \times 10^{-3}$

$\frac{\Delta R}{R} = 2 \times 10^{-3}$

Step 2 – list the excitation voltage: $V_{ex} = 4$ V.

Step 3 – substitute into the bridge formula: $V_o = \frac{4}{4} \times 2 \times 10^{-3}$

Step 4 – simplify the excitation factor: $\frac{4}{4} = 1$

$V_o = 1 \times 2 \times 10^{-3}$

Step 5 – convert to millivolts: $V_o = 2 \times 10^{-3}\ \text{V} = 2\ \text{mV}$

Final Answer: $V_o = 2\ \text{mV} \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q22

Q23.

Solution

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

Step 1 – list the data: $A_d = 1000$, $A_c = 0.1$.

Step 2 – form the ratio: $\frac{A_d}{A_c} = \frac{1000}{0.1} = 10000$

Step 3 – take the base-10 logarithm: $\log_{10}(10000) = 4$

Step 4 – multiply by 20: $\text{CMRR}_{\text{dB}} = 20 \times 4$

$\text{CMRR}_{\text{dB}} = 80\ \text{dB}$

Final Answer: $\text{CMRR} = 80\ \text{dB} \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q23

Q24.

Solution

Concept – working principle of an LVDT: An LVDT has one primary and two secondary coils; moving the ferromagnetic core changes the magnetic coupling between them.

Step 1 – identify the physical effect: As the core moves, the mutual inductance between primary and secondaries changes, altering the induced secondary voltages.

Step 2 – relate to displacement: The differential secondary output is proportional to core displacement, giving a linear electromagnetic-induction transducer.

Why the other options are wrong:

- A, piezoelectric: is the principle of a piezo force/pressure sensor.
- B, resistance change: is the principle of a potentiometer or strain gauge.
- C, capacitance change: is the principle of a capacitive displacement sensor.

Final Answer: mutual inductance (electromagnetic induction) $\Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q24

Q25.

Solution

Concept – thermoelectric temperature sensing: A junction of two dissimilar metals develops an EMF that depends on the junction temperature.

Step 1 – name the effect: The generation of an EMF from a temperature difference across a junction of two dissimilar conductors is the Seebeck effect.

Step 2 – relate to the thermocouple: A thermocouple exploits the Seebeck EMF between a measuring junction and a reference junction to indicate temperature.

Why the other options are wrong:

- A, Peltier effect: is the reverse process (current produces heating/cooling at a junction), used in thermoelectric coolers.
- B, piezoresistive effect: relates resistance change to mechanical strain.
- C, Hall effect: produces a voltage from a magnetic field acting on a current, used in magnetic sensors.

Final Answer: Seebeck effect $\Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q25

Q26.

Solution

Concept – Nyquist sampling theorem: To reconstruct a band-limited signal without aliasing, sample at more than twice the highest frequency: $f_s \geq 2f_{\text{max}}$.

Step 1 – list the data: $f_{\text{max}} = 500$ Hz.

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

Step 3 – substitute: $f_{s,\text{min}} = 2 \times 500$

$f_{s,\text{min}} = 1000$ Hz

Why the other options are wrong:

- B, 500 Hz: equals f_{max} only, well below the Nyquist rate.
- C, 250 Hz: is below even f_{max} and would alias badly.
- D, 2000 Hz: works but is not the *minimum* required.

Final Answer: $f_{s,\text{min}} = 1000 \text{ Hz} \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q26

Q27.

Solution

Concept – alias frequency for undersampling: When $f < f_s < 2f$, the alias appears at $f_{\text{alias}} = |f_s - f|$.

Step 1 – list the data: Signal $f = 300$ Hz, sampling $f_s = 500$ Hz.

Step 2 – check that aliasing occurs: The Nyquist rate is $2 \times 300 = 600$ Hz, and $f_s = 500 < 600$, so the signal is undersampled.

Step 3 – compute the alias: $f_{\text{alias}} = |f_s - f| = |500 - 300|$

$f_{\text{alias}} = 200$ Hz

Final Answer: $f_{\text{alias}} = 200 \text{ Hz} \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q27

Q28.

Solution

Concept – frequency response of a moving-average filter: Averaging neighbouring samples smooths the signal, attenuating rapid (high-frequency) fluctuations while passing slow (low-frequency) trends.

Step 1 – describe the time-domain action: Each output is the mean of N successive input samples, which blurs sharp changes.

Step 2 – translate to the frequency domain: Its magnitude response is largest at DC and rolls off (with a sinc shape) towards higher frequencies.

Step 3 – classify: Because it passes low frequencies and suppresses high ones, it is a low-pass filter.

Why the other options are wrong:

- A, high-pass: would attenuate the DC/low frequencies, the opposite of averaging.
- B, band-pass: passes a middle band and blocks both DC and high frequencies, which averaging does not do.
- D, all-pass: would leave the magnitude unchanged, but averaging clearly attenuates high frequencies.

Final Answer: low-pass filter $\Rightarrow \boxed{C}$

Answer: (C) Go Back to Q28

Q29.

Solution

Concept – removing narrow-band interference: Power-line interference at 50 Hz is a single narrow frequency, best removed with a filter that rejects only that frequency.

Step 1 – read the magnitude response: The plot passes all frequencies at nearly unity gain except for a deep, narrow dip at 50 Hz.

Step 2 – name that response: A response that blocks one narrow band while passing the rest is a notch (band-reject) filter.

Step 3 – match to the requirement: Centring the notch at 50 Hz removes power-line interference while leaving the ECG's diagnostic content essentially untouched.

Why the other options are wrong:

- A, low-pass at 50 Hz: would remove all ECG content above 50 Hz, discarding useful QRS information.
- B, high-pass: would remove the low-frequency ECG baseline and P/T waves.
- C, differentiator: emphasises high frequencies rather than rejecting 50 Hz.

Final Answer: notch (band-reject) filter at 50 Hz $\Rightarrow \boxed{\text{D}}$

Answer: (D) 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, $V_n = 0.01$ V.

Step 2 – form the amplitude ratio: $\frac{V_s}{V_n} = \frac{1}{0.01} = 100$

Step 3 – take the base-10 logarithm: $\log_{10}(100) = 2$

Step 4 – multiply by 20: $\text{SNR}_{\text{dB}} = 20 \times 2$

$\text{SNR}_{\text{dB}} = 40$ dB

Final Answer: SNR $= 40$ dB $\Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q30

Q31.

Solution

Concept – the Hounsfield (CT number) scale: $\text{HU} = 1000 \cdot \frac{\mu - \mu_{\text{water}}}{\mu_{\text{water}}}$, which is calibrated so water and air take fixed values.

Step 1 – evaluate the scale for water: Setting $\mu = \mu_{\text{water}}$ gives $\text{HU} = 1000 \times \frac{0}{\mu_{\text{water}}} = 0$.

Step 2 – state the reference values: Water $= 0$ HU and air $= -1000$ HU by definition.

Why the other options are wrong:

- B, -1000 HU: is the value assigned to air, not water.
- C, $+1000$ HU: is roughly the value for dense cortical bone.
- D, $+100$ HU: does not correspond to a calibration reference.

Final Answer: water $= 0$ HU $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q31

Q32.

Solution

Concept – Beer–Lambert attenuation of X-rays: $I = I_0 e^{-\mu x}$, so the transmitted fraction is $\dfrac{I}{I_0} = e^{-\mu x}$.

Step 1 – list the data: $\mu = 0.693$ cm^{-1}, $x = 1$ cm.

Step 2 – form the exponent: $\mu x = 0.693 \times 1 = 0.693$

Step 3 – evaluate the exponential: $\dfrac{I}{I_0} = e^{-0.693}$

Step 4 – use $e^{-0.693} = 0.5$**:** $\dfrac{I}{I_0} = 0.50$

Step 5 – interpret: Half the beam is transmitted, so $x = 1$ cm here is one half-value layer (HVL) of the material.

Final Answer: $I/I_0 = 0.50 \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q32

Q33.

Solution

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

Step 1 – list the data: $\rho = 1000$ kg/m^3, $c = 1540$ m/s.

Step 2 – multiply: $Z = 1000 \times 1540$

$Z = 1{,}540{,}000$

Step 3 – express in powers of ten: $Z = 1.54 \times 10^6$ kg m^{-2}s^{-1}

Step 4 – note the unit: This unit (kg m^{-2}s^{-1}) is the rayl; soft tissue is about 1.5 MRayl.

Final Answer: $Z = 1.54 \times 10^6$ kg m^{-2}s^{-1} $\Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q33

Q34.

Solution

Concept – assumed speed of sound in soft tissue: Ultrasound scanners convert echo time to depth using a single average speed of sound.

Step 1 – recall the standard value: The conventional value for soft tissue is 1540 m/s.

Step 2 – relate to imaging: Depth $d = \frac{ct}{2}$ (the factor 2 for the round trip), computed with $c = 1540$ m/s.

Why the other options are wrong:

- B, 340 m/s: is the speed of sound in air, not tissue.
- C, 3000 m/s: is closer to the speed in bone, not the assumed soft-tissue value.
- D, 15400 m/s: is off by a factor of ten and unphysical for tissue.

Final Answer: $c \approx 1540$ m/s $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q34

Q35.

Solution

Concept – source of the MRI signal: MRI detects nuclei that possess a magnetic moment and are abundant in the body.

Step 1 – identify the most abundant MR-active nucleus: The hydrogen nucleus (a single proton) is extremely abundant in water and fat throughout the body and has a strong magnetic moment.

Step 2 – link to the signal: Clinical MRI therefore images the proton (hydrogen) nuclear magnetic resonance signal.

Why the other options are wrong:

- A, carbon-13: is a low-abundance nucleus used only in specialised spectroscopy.
- B, oxygen-16: has no net nuclear spin and gives no NMR signal.
- D, sodium-23: is used in niche research imaging but gives a far weaker signal than protons.

Final Answer: hydrogen (protons) $\Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q35

Q36.

Solution

Concept – stiffness of cortical bone: The Young's modulus quantifies the elastic stiffness of the bone tissue.

Step 1 – recall the accepted range: Adult cortical bone has a longitudinal Young's modulus of roughly 15–20 GPa.

Step 2 – pick the representative value: About 18 GPa lies squarely in this range.

Why the other options are wrong:

- B, 200 GPa: is the modulus of steel, about an order of magnitude too stiff for bone.
- C, 1.8 GPa: is too low; it is nearer to a stiff polymer.
- D, 70 GPa: is the modulus of aluminium, still well above bone.

Final Answer: $E \approx 18 \text{ GPa} \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q36

Q37.

Solution

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

Step 1 – list the data: $F = 1500$ N, $A = 300$ mm^2.

Step 2 – substitute: $\sigma = \dfrac{1500}{300}$

Step 3 – divide: $\sigma = 5 \text{ N/mm}^2$

Step 4 – convert the unit: $1 \text{ N/mm}^2 = 1$ MPa, so $\sigma = 5$ MPa.

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

Answer: (A) Go Back to Q37

Q38.

Solution

Concept – Hooke's law in the elastic range: $\varepsilon = \dfrac{\sigma}{E}$.

Step 1 – list the data in consistent units: $\sigma = 18 \text{ MPa} = 18 \times 10^6$ Pa, $E = 18 \text{ GPa} = 18 \times 10^9$ Pa.

Step 2 – substitute: $\varepsilon = \dfrac{18 \times 10^6}{18 \times 10^9}$

Step 3 – cancel the coefficient 18: $\varepsilon = \dfrac{10^6}{10^9}$

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

$\varepsilon = 0.001$

Final Answer: $\varepsilon = 0.001 \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q38

Q39.

Solution

Concept – area under the stress–strain curve: The area under a stress–strain curve has units of stress (J/m^3) and equals energy absorbed per unit volume.

Step 1 – interpret the shaded region: The area from zero strain to fracture is $\int \sigma \, d\varepsilon$, the strain energy density stored up to failure.

Step 2 – name that quantity: Energy absorbed per unit volume up to fracture is the material's toughness (modulus of toughness).

Why the other options are wrong:

- B, stiffness: is the *slope* of the elastic part (Young's modulus), not the area.
- C, yield strength: is a single stress value where plastic flow begins, not an area.
- D, Poisson's ratio: relates lateral to axial strain and is unrelated to this area.

Final Answer: toughness (energy per unit volume) $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q39

Q40.

Solution

Concept – material selection for orthopaedic implants: Load-bearing implants demand high strength, corrosion resistance in body fluids and biocompatibility.

Step 1 – match requirements to a material: Titanium alloy (Ti–6Al–4V) is strong, light, corrosion resistant and forms a stable, biocompatible oxide layer.

Step 2 – confirm clinical use: It is the standard choice for hip stems, bone plates and dental implants.

Why the other options are wrong:

- A, copper: corrodes and is toxic to tissue.
- C, mild steel: corrodes readily in body fluids and lacks biocompatibility.
- D, lead: is soft and highly toxic.

Final Answer: titanium alloy (Ti–6Al–4V) $\Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q40

Q41.

Solution

Concept – moment (torque) balance of the forearm lever: For static equilibrium the muscle moment about the elbow equals the load moment: $F_m \cdot d_m = W \cdot d_W$.

Step 1 – list the data: $W = 50$ N at $d_W = 30$ cm; muscle acts at $d_m = 5$ cm.

Step 2 – write the moment balance about the elbow: $F_m \times 5 = 50 \times 30$

Step 3 – evaluate the right-hand side: $50 \times 30 = 1500$

Step 4 – solve for F_m: $F_m = \dfrac{1500}{5}$

$F_m = 300$ N

Step 5 – sanity check: The muscle's lever arm (5 cm) is six times shorter than the load's (30 cm), so it must supply six times the weight: $6 \times 50 = 300$ N, which agrees.

Final Answer: $F_m = 300$ N $\Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q41

Q42.

Solution

Concept – closed-loop transfer function with negative feedback: For a forward path $G(s)$ and feedback $H(s)$, $\dfrac{C(s)}{R(s)} = \dfrac{G(s)}{1 + G(s)H(s)}$.

Step 1 – write the summing-junction equation: The error is $E(s) = R(s) - H(s)C(s)$ (negative feedback).

Step 2 – write the forward-path relation: $C(s) = G(s)E(s) = G(s)\big[R(s) - H(s)C(s)\big]$

Step 3 – expand: $C(s) = G(s)R(s) - G(s)H(s)C(s)$

Step 4 – collect the $C(s)$ terms: $C(s) + G(s)H(s)C(s) = G(s)R(s)$

$C(s)\big[1 + G(s)H(s)\big] = G(s)R(s)$

Step 5 – solve for the ratio: $\dfrac{C(s)}{R(s)} = \dfrac{G(s)}{1 + G(s)H(s)}$

Why the other options are wrong:

- A, $\dfrac{G}{1 - GH}$: is the *positive*-feedback result.
- B and C: are not the standard single-loop closed-loop form.

Final Answer: $\dfrac{C}{R} = \dfrac{G}{1 + GH} \Rightarrow \boxed{\text{D}}$

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.

Step 1 – compare with the given function: $\dfrac{1}{2s + 1}$ has the form $\dfrac{1}{\tau s + 1}$ with the coefficient of s equal to 2.

Step 2 – identify the time constant: $\tau = 2$ s.

Step 3 – interpret: The step response reaches 63.2% of its final value after one time constant, i.e. after 2 s.

Why the other options are wrong:

- A, 0.5 s: is the reciprocal $1/\tau$ (the pole magnitude), not the time constant.
- B, 1 s: ignores the coefficient of s.
- D, 4 s: is the approximate settling time ($\approx 2\tau$), not τ itself.

Final Answer: $\tau = 2\ \text{s} \Rightarrow \boxed{\text{C}}$

Answer: (C) **Go Back to Q43**

Q44.

Solution

Concept – damping ratio and transient response: The value of ζ classifies a second-order system's response.

Step 1 – recall the classification: $\zeta = 0$ undamped; $0 < \zeta < 1$ underdamped; $\zeta = 1$ critically damped; $\zeta > 1$ overdamped.

Step 2 – apply to $\zeta = 1$: The system is critically damped, with two equal real poles.

Step 3 – describe the response: It returns to steady state as fast as possible without any overshoot or oscillation.

Why the other options are wrong:

- A, undamped: requires $\zeta = 0$.
- B, underdamped: requires $0 < \zeta < 1$ and shows overshoot.
- D, overdamped: requires $\zeta > 1$ and is slower than critical damping.

Final Answer: critically damped $\Rightarrow \boxed{C}$

Answer: (C) Go Back to Q44

Q45.

Solution

Concept – order of a system: The order equals the highest power of s in the characteristic equation, i.e. the number of closed-loop poles.

Step 1 – read the characteristic equation: $s^3 + 2s^2 + 3s + 4 = 0$.

Step 2 – find the highest power of s: The leading term is s^3, so the highest power is 3.

Step 3 – state the order: The system is third order (three poles).

Final Answer: order $= 3 \Rightarrow \boxed{B}$

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: $C = 32\ \mu\text{F} = 32 \times 10^{-6}$ F, $V = 5000$ V.

Step 2 – square the voltage: $V^2 = (5000)^2 = 25 \times 10^6$ V^2

Step 3 – multiply by the capacitance: $CV^2 = 32 \times 10^{-6} \times 25 \times 10^6$

Step 4 – combine coefficients and powers of ten: $32 \times 25 = 800$ and $10^{-6} \times 10^6 = 10^0 = 1$, so $CV^2 = 800$

Step 5 – apply the factor one-half: $E = \frac{1}{2} \times 800$

$E = 400$ J

Final Answer: $E = 400$ J $\Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q46

Answer Key

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