# GATE Biomedical Engineering

## Sample Paper – 2

**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 $\approx -70$ mV, speed of sound in soft tissue $\approx 1540$ m/s) unless stated otherwise.

## Human Anatomy and Physiology

**Q1.** In the standard limb-lead electrocardiogram, the three bipolar (Einthoven) leads are formed from the right-arm (RA), left-arm (LA) and left-leg (LL) electrodes. Standard **Lead II** records the potential difference given by: **[1 mark]**

(A) left arm (LA) minus right arm (RA)

(B) left leg (LL) minus left arm (LA)

(C) left leg (LL) minus right arm (RA)

(D) right arm (RA) minus left leg (LL)

**Q2.** The typical normal resting arterial blood pressure (systolic over diastolic) of a healthy young adult is nearest to: **[1 mark]**

(A) 120/80 mmHg

(B) 200/150 mmHg

(C) 80/50 mmHg

(D) 160/110 mmHg

**Q3.** A healthy adult heart beats at a rate of 75 beats per minute. The duration of one complete cardiac cycle (one heartbeat) is: **[1 mark]**

(A) 0.2 s

(B) 1.5 s

(C) 0.8 s

(D) 8 s

**Q4.** The chamber of the heart that pumps oxygenated blood out into the systemic circulation through the aorta is the: **[1 mark]**

(A) left ventricle

(B) right ventricle

(C) left atrium

(D) right atrium

**Q5.** On a normal adult electrocardiogram, the **PR interval** (measured from the onset of the P wave to the onset of the QRS complex) normally lies in the range: **[1 mark]**

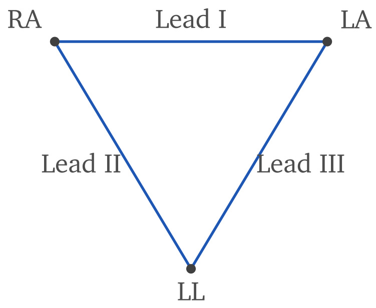
(A) 0.40–0.50 s

(B) 0.01–0.02 s

(C) 0.12–0.20 s

(D) 0.60–0.80 s

**Q6.** The three bipolar limb leads sit on Einthoven's triangle as shown. By Einthoven's law the lead voltages satisfy Lead II = Lead I + Lead III. If at one instant Lead I = 0.5 mV and Lead III = 0.7 mV, the Lead II voltage is: **[1 mark]**




(A) 0.2 mV

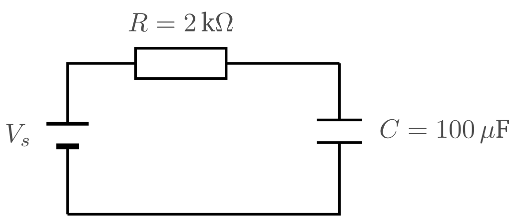
(B) 1.2 mV

(C) 0.35 mV

(D) 0.6 mV

## Electric Circuits, Signals and Systems

**Q7.** In the series $RC$ circuit shown, a step voltage is applied to charge the capacitor through the resistor, with $R = 2$ k$\Omega$ and $C = 100$ $\mu$F. The time constant $\tau = RC$ of the transient response is: **[1 mark]**




(A) 2 s

(B) 20 s

(C) 0.02 s

(D) 0.2 s

**Q8.** A capacitor is charged from zero through a resistor by a constant DC source (a first-order $RC$ transient). After a time equal to *one* time constant has elapsed, the capacitor voltage has risen to the following fraction of its final steady-state value: **[1 mark]**

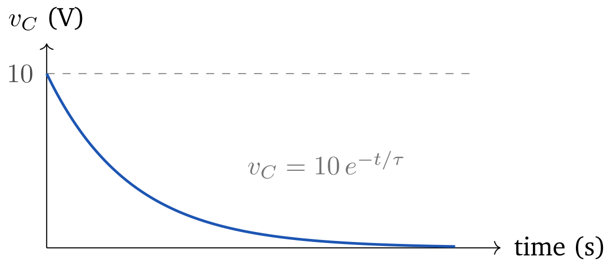
(A) $37\%$

(B) $100\%$

(C) $50\%$

(D) $63.2\%$

**Q9.** A capacitor initially charged to $10$ V is discharged through a resistor, giving the decaying transient shown. The time constant is $\tau = 0.2$ s. The capacitor voltage remaining after one time constant ($t = 0.2$ s) is nearest to: **[1 mark]**




(A) $6.3$ V

(B) $10$ V

(C) $3.7$ V

(D) $0$ V

**Q10.** 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) $sC$

(C) $sL$

(D) $R$

**Q11.** For an ideal capacitor of capacitance $C$, the instantaneous terminal current $i$ and terminal voltage $v$ are related by: **[1 mark]**

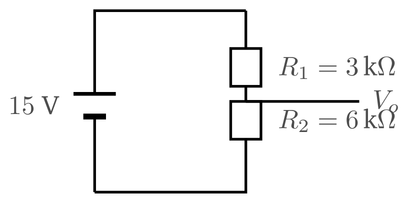
(A) $i = C\dfrac{dv}{dt}$

(B) $v = L\dfrac{di}{dt}$

(C) $i = \dfrac{v}{R}$

(D) $i = Cv$

**Q12.** In the resistive voltage divider shown, a 15 V source is applied across $R_1 = 3$ kΩ in series with $R_2 = 6$ kΩ. The output voltage $V_o$ taken across $R_2$ is: **[1 mark]**



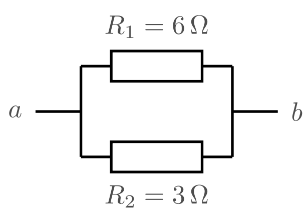

(A) 5 V

(B) 10 V

(C) 7.5 V

(D) 15 V

**Q13.** Two resistors, $R_1 = 6\ \Omega$ and $R_2 = 3\ \Omega$, are connected in parallel between the terminals $a$ and $b$, as shown. The equivalent resistance seen between $a$ and $b$ is: **[1 mark]**




(A) 9 Ω

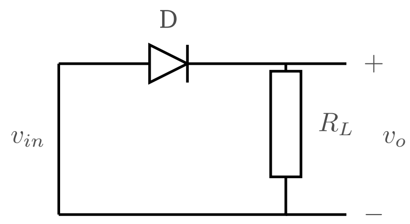
(B) 18 Ω

(C) 4.5 Ω

(D) $2\ \Omega$

## Analog and Digital Electronics

**Q14.** The half-wave rectifier shown uses an ideal diode and is driven by a sinusoidal input of peak value $V_m = 10$ V. The average (DC) value of the output voltage across the load, $V_{dc} = V_m/\pi$, is nearest to: **[1 mark]**




(A) 6.37 V

(B) 10 V

(C) 3.18 V

(D) 5 V

**Q15.** A full-wave (centre-tapped or bridge) rectifier with an ideal-diode model is driven by a sinusoid of peak value $V_m = 10$ V. The average (DC) value of its rectified output, $V_{dc} = 2V_m/\pi$, is nearest to: **[1 mark]**

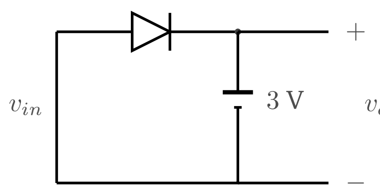
(A) 3.18 V

(B) 10 V

(C) 6.37 V

(D) 5 V

**Q16.** In the biased diode clipper shown, the diode conducts and clamps the output whenever the input rises above the 3 V reference battery. For a 10 V-peak sinusoidal input, the maximum (most positive) value the output can reach is: **[1 mark]**



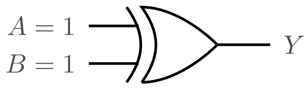
(A) $+10$ V

(B) $+3$ V

(C) $-3$ V

(D) $0$ V

**Q17.** For the two-input exclusive-OR (XOR) 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) $0$

(C) high impedance

(D) undefined

**Q18.** A digital system must represent $1024$ distinct signal levels using a binary code. The minimum number of bits required is: **[1 mark]**

(A) $10$

(B) $8$

(C) $12$

(D) $1024$

**Q19.** A $12$-bit analog-to-digital converter 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) $4$ mV

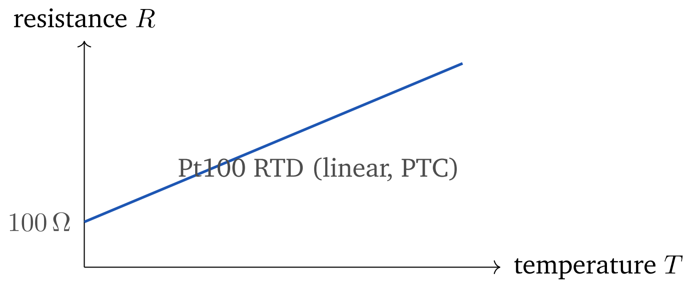
(B) $0.5$ mV

(C) $1$ mV

(D) $2$ mV

## Sensors, Bioinstrumentation and Measurements

**Q20.** The platinum resistance-temperature detector (RTD) known as a "Pt100" has a resistance–temperature curve that is nearly linear with a positive slope, as sketched. By definition, its nominal resistance at $0$ °C is: **[1 mark]**



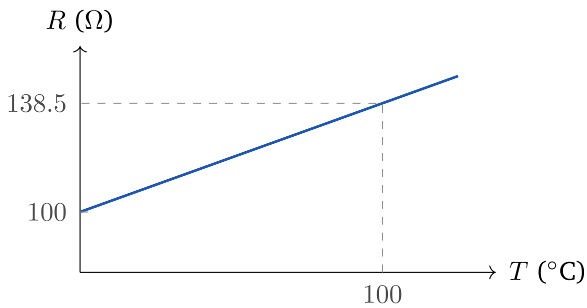

(A) $100\ \Omega$

(B) $1000\ \Omega$

(C) $50\ \Omega$

(D) $10\ \Omega$

**Q21.** A Pt100 RTD has a resistance $R_0 = 100\ \Omega$ at $0$ °C and a temperature coefficient $\alpha = 0.00385$ °C$^{-1}$. Using the linear model $R = R_0(1 + \alpha T)$, its resistance at $T = 100$ °C read from the transfer curve is: **[2 marks]**




(A) $100\ \Omega$

(B) $385\ \Omega$

(C) $103.85\ \Omega$

(D) $138.5\ \Omega$

**Q22.** A self-heating bead thermistor has a dissipation constant of $2$ mW/°C (the electrical power needed to raise its body temperature by $1$ °C above ambient). If the measuring current makes it dissipate $4$ mW, the self-heating temperature rise (error) is: **[2 marks]**

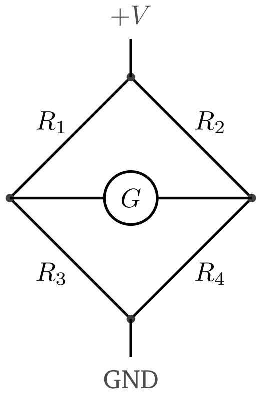
(A) $0.5\ ^\circ$C

(B) $8\ ^\circ$C

(C) $2\ ^\circ$C

(D) $4\ ^\circ$C

**Q23.** The Wheatstone bridge shown is balanced (the galvanometer $G$ reads zero) with arms $R_1 = 200\ \Omega$, $R_2 = 400\ \Omega$ and $R_3 = 300\ \Omega$. Using the balance condition $\dfrac{R_1}{R_2} = \dfrac{R_3}{R_4}$, the value of $R_4$ is: **[2 marks]**




(A) $150\ \Omega$

(B) $600\ \Omega$

(C) $450\ \Omega$

(D) $200\ \Omega$

**Q24.** A biopotential (instrumentation) amplifier has a differential-mode gain $A_d = 2000$ and a common-mode gain $A_c = 0.2$. Its common-mode rejection ratio in decibels, $\text{CMRR}_{\text{dB}} = 20\log_{10}(A_d/A_c)$, is: **[2 marks]**

(A) $80$ dB

(B) $40$ dB

(C) $100$ dB

(D) 60 dB

**Q25.** Which transducer is best suited to measuring *rapidly varying* (dynamic) blood pressure or heart sounds, converting mechanical stress directly into an electric charge, but is unable to hold a reading for a truly static (DC) pressure? **[2 marks]**

(A) resistance-temperature detector (RTD)

(B) linear variable differential transformer (LVDT)

(C) piezoelectric crystal

(D) thermocouple

## Biomedical Signal Processing

**Q26.** A diagnostic-quality ECG signal is generally taken to occupy the band 0.05 Hz to 150 Hz. To digitise it without aliasing, the minimum (Nyquist) sampling frequency must exceed: **[2 marks]**

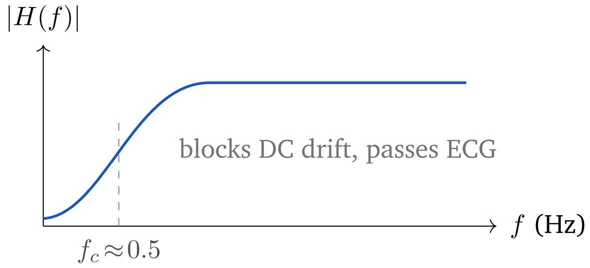
(A) 150 Hz

(B) 1500 Hz

(C) 75 Hz

(D) 300 Hz

**Q27.** The recorded ECG shows a slow, wandering baseline (baseline drift) caused by respiration and gradual electrode-skin changes, at frequencies below about 0.5 Hz. The magnitude response sketched removes this drift while preserving the ECG. This filter is a: **[2 marks]**




(A) high-pass filter with cut-off $\approx 0.5$ Hz

(B) low-pass filter

(C) all-pass filter

(D) pure integrator

**Q28.** A recorded ECG is contaminated by high-frequency electromyographic (muscle) noise well above the diagnostic band. To suppress this noise while preserving the QRS complex, the most appropriate filter is a: **[2 marks]**

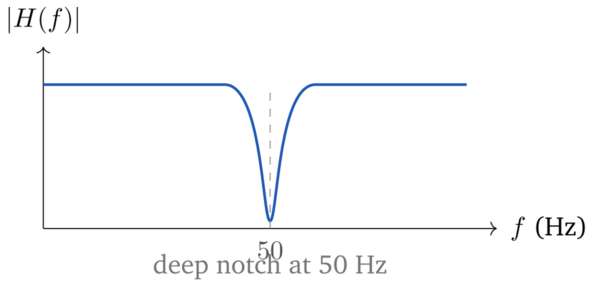
(A) high-pass filter

(B) notch filter centred at 50 Hz

(C) pure differentiator

(D) low-pass filter with cut-off $\approx$ 100–150 Hz

**Q29.** The magnitude response shown has a single deep, narrow dip at 50 Hz and is nearly flat elsewhere. It is the filter of choice for removing power-line interference from an ECG while leaving the rest of the spectrum intact. This filter is a: **[2 marks]**




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

(B) low-pass filter

(C) high-pass filter

(D) all-pass filter

**Q30.** A recorded biosignal has a signal amplitude of 2 V (RMS) and a noise amplitude of 0.02 V (RMS). The signal-to-noise ratio in decibels, $\mathrm{SNR_{dB}} = 20\log_{10}(V_s/V_n)$, is: **[2 marks]**

(A) 20 dB

(B) 40 dB

(C) 60 dB

(D) 80 dB

## Medical Imaging Systems

**Q31.** In a diagnostic X-ray tube used for radiography, the X-rays are produced when the high-speed electrons emitted by the heated filament strike and are abruptly decelerated at the: **[2 marks]**

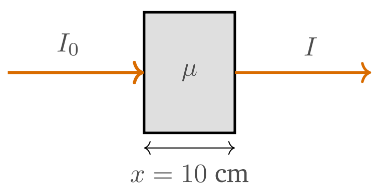
(A) anode (metal target, usually tungsten)

(B) cathode filament

(C) glass envelope

(D) collimator slit

**Q32.** A monoenergetic X-ray beam of incident intensity $I_0$ passes through a tissue slab of thickness $x$ and linear attenuation coefficient $\mu$, as shown, following $I = I_0 \, e^{-\mu x}$. For $\mu = 0.1$ cm$^{-1}$ and $x = 10$ cm, the transmitted fraction $I/I_0$ is nearest to: **[2 marks]**




(A) 0.90

(B) 0.10

(C) 0.50

(D) 0.37

**Q33.** For a material with linear attenuation coefficient $\mu = 0.693$ cm$^{-1}$, the half-value layer (HVL) – the thickness that reduces the X-ray beam intensity to one-half – is HVL $= \dfrac{\ln 2}{\mu}$. Its value here is: **[2 marks]**

(A) $0.693$ cm

(B) $2$ cm

(C) $0.5$ cm

(D) $1$ cm

**Q34.** On a plain radiograph, bone appears bright (white) against the darker soft tissue chiefly because, per unit path length, bone has a much larger: **[2 marks]**

(A) linear attenuation coefficient for X-rays

(B) speed of sound

(C) proton (spin) density

(D) electrical conductivity

**Q35.** In X-ray computed tomography (CT), the classical algorithm used to reconstruct a cross-sectional image from the many angular projection measurements is: **[2 marks]**

(A) the fast Fourier transform of the raw radiograph

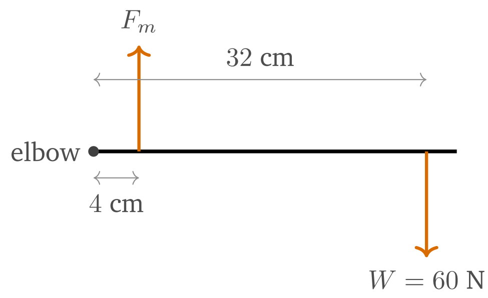
(B) filtered back-projection

(C) region growing

(D) histogram equalisation

## Biomechanics and Biomaterials

**Q36.** The forearm is modelled as a lever pivoted at the elbow, as shown. A weight $W = 60$ N is held in the hand at a horizontal distance of $32$ cm from the elbow, while the biceps muscle force $F_m$ acts vertically upward at $4$ cm from the elbow. Taking moments about the elbow for static equilibrium, the required muscle force $F_m$ is: **[2 marks]**



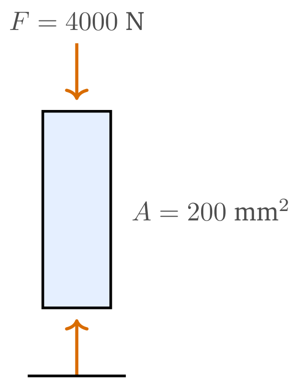

(A) 60 N

(B) 240 N

(C) 7.5 N

(D) 480 N

**Q37.** A short bone segment of uniform cross-sectional area $A = 200$ mm$^2$ carries a purely axial compressive load $F = 4000$ N, as shown. The average normal (axial) stress $\sigma = F/A$ in the segment is: **[2 marks]**




(A) 2 MPa

(B) 20 MPa

(C) 200 MPa

(D) 0.2 MPa

**Q38.** During normal human walking, the interval of the gait cycle in which the foot is in contact with the ground and bearing weight is called the: **[2 marks]**

(A) stance phase

(B) swing phase

(C) double-float phase

(D) recovery phase

**Q39.** In a normal adult walking gait cycle (heel-strike of one foot to the next heel-strike of the same foot), the stance phase occupies approximately what percentage of the whole cycle? **[2 marks]**

(A) $10\%$

(B) $100\%$

(C) $40\%$

(D) $60\%$

**Q40.** A specimen of cortical bone with Young's modulus $E = 20$ GPa is loaded within its linear-elastic range to an axial stress $\sigma = 40$ MPa. The axial strain produced, $\varepsilon = \sigma/E$, is: **[2 marks]**

(A) $0.02$

(B) $0.002$

(C) $0.2$

(D) $0.0002$

**Q41.** In a total hip-replacement prosthesis, which bio-inert polymer is most commonly used for the acetabular (socket) bearing surface that articulates against the metal or ceramic femoral head, because of its low friction and wear resistance? **[2 marks]**

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

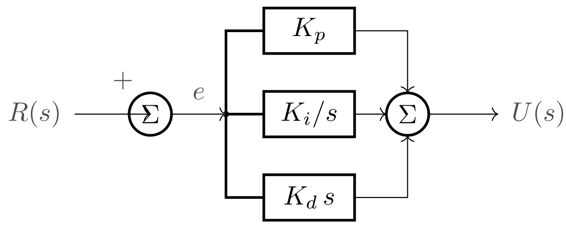
(B) mild (carbon) steel

(C) copper

(D) magnesium

## Control Systems and Medical Instrumentation

**Q42.** A three-term PID controller $u(t) = K_p\, e(t) + K_i \int e\, dt + K_d \frac{de}{dt}$ is used in a closed-loop medical device, as shown. The term that anticipates the trend of the error (responds to its rate of change) and so improves the transient response and damping is the: **[2 marks]**




(A) integral term

(B) derivative term

(C) proportional term

(D) bias term

**Q43.** In the same PID controller $u(t) = K_p\, e + K_i \int e\, dt + K_d \frac{de}{dt}$, the term whose action drives the steady-state error to zero (by accumulating the error over time) is the: **[2 marks]**

(A) proportional term

(B) derivative term

(C) integral term

(D) feed-forward term

**Q44.** A first-order physiological sensor has the transfer function $\frac{Y(s)}{X(s)} = \frac{5}{4s+1}$. The time constant of this system is: **[2 marks]**

(A) $5$ s

(B) $4$ s

(C) $0.25$ s

(D) $1$ s

**Q45.** A unity-feedback control system has the open-loop transfer function $G(s) =$

$\dfrac{10}{s(s+2)}$. Based on the number of poles it has at the origin ($s = 0$), the system is classified as: **[2 marks]**

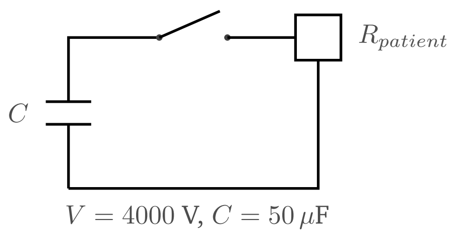
(A) Type 0

(B) Type 1

(C) Type 2

(D) Type 3

**Q46.** The defibrillator shown stores energy in a capacitor $C = 50\ \mu$F charged to $V = 4000$ V and then discharges it through the patient. The stored (and delivered) energy, $E = \frac{1}{2}CV^2$, is: **[2 marks]**




(A) 100 J

(B) 200 J

(C) 800 J

(D) 400 J

## Detailed Solutions

### Q1.

**Solution**

**Concept – Einthoven's bipolar limb leads:** Each standard limb lead is defined as a signed difference between two of the three electrodes RA, LA and LL.

**Step 1 – write the three lead definitions:** Lead I $= V_{LA} - V_{RA}$.

Lead II $= V_{LL} - V_{RA}$.

Lead III $= V_{LL} - V_{LA}$.

**Step 2 – select Lead II:** The definition of Lead II is $V_{LL} - V_{RA}$, i.e. left leg minus right arm.

**Why the other options are wrong:**

- A, LA − RA: is Lead I.
- B, LL − LA: is Lead III.
- D, RA − LL: is the negative of Lead II (wrong polarity).

**Final Answer:** Lead II = left leg − right arm $\Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q1

### Q2.

**Solution**

**Concept – normal arterial blood pressure:** Systemic arterial pressure swings between a peak (systolic) and a trough (diastolic) with each cardiac cycle.

**Step 1 – recall the reference values:** For a healthy young adult, systolic pressure is about $120$ mmHg and diastolic about $80$ mmHg.

**Step 2 – state the pair:** The conventional "normal" reading is therefore $120/80$ mmHg.

**Why the other options are wrong:**

- B, $200/150$ mmHg: is severe hypertension.
- C, $80/50$ mmHg: is hypotension.
- D, $160/110$ mmHg: is stage-2 hypertension.

**Final Answer:** $120/80$ mmHg $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q2

## Q3.

**Solution**

**Concept – period of the cardiac cycle:** The cardiac cycle time is the reciprocal of the heart rate expressed per second.

**Step 1 – convert the heart rate to beats per second:** $75$ beats/min $= \frac{75}{60}$ beats/s $= 1.25$ beats/s.

**Step 2 – take the reciprocal to get the period:** $T = \frac{1}{1.25}$

$T = 0.8$ s.

**Step 3 – interpret:** Each heartbeat, from one R wave to the next, lasts about $0.8$ s at $75$ bpm.

**Final Answer:** $T = 0.8$ s $\Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q3

## Q4.

**Solution**

**Concept – pump chambers of the heart:** The two ventricles are the pumping chambers; the atria are the receiving chambers.

**Step 1 – trace the systemic side:** Oxygenated blood returns from the lungs to the left atrium, passes to the left ventricle, and is ejected into the aorta.

**Step 2 – identify the ejecting chamber:** The left ventricle generates the high pressure that drives blood through the systemic circulation via the aorta.

**Why the other options are wrong:**

- B, right ventricle: pumps de-oxygenated blood to the lungs (pulmonary circulation).
- C and D, the atria: are low-pressure receiving chambers, not systemic pumps.

**Final Answer:** left ventricle $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q4

## Q5.

**Solution**

**Concept – the PR interval on the ECG:** The PR interval spans atrial depolarisation plus the conduction delay at the AV node, from the start of P to the start of QRS.

**Step 1 – recall the normal range:** In a healthy adult the PR interval is $0.12$ to $0.20$ s (about $3$ to $5$ small squares at $25$ mm/s).

**Step 2 – interpret the limits:** A value above $0.20$ s indicates first-degree AV block; a very short value suggests pre-excitation.

**Why the other options are wrong:**

- A, $0.40$–$0.50$ s: is far too long (marked AV block).
- B, $0.01$–$0.02$ s: is unphysiologically short.
- D, $0.60$–$0.80$ s: is of the order of the whole cardiac cycle, not the PR interval.

**Final Answer:** $0.12$–$0.20$ s $\Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q5

## Q6.

**Solution**

**Concept – Einthoven's law:** The three limb-lead voltages are not independent; they satisfy Lead II $=$ Lead I $+$ Lead III at every instant.

**Step 1 – list the data:** Lead I $= 0.5$ mV, Lead III $= 0.7$ mV.

**Step 2 – apply Einthoven's law:** Lead II $=$ Lead I $+$ Lead III

**Step 3 – substitute:** Lead II $= 0.5 + 0.7$

Lead II $= 1.2$ mV.

**Why the other options are wrong:**

- A, $0.2$ mV: is the *difference* of the two leads, not the sum.
- C, $0.35$ mV: is the product, which has no physical meaning here.
- D, $0.6$ mV: is the average of the two leads.

**Final Answer:** Lead II $= 1.2$ mV $\Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q6

## Q7.

**Solution**

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

**Step 1 – list the data in base units:** $R = 2\ \text{k}\Omega = 2 \times 10^3\ \Omega$, $C = 100\ \mu\text{F} = 100 \times 10^{-6}$ F.

**Step 2 – substitute:** $\tau = (2 \times 10^3)(100 \times 10^{-6})$

**Step 3 – multiply the coefficients:** $2 \times 100 = 200$

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

**Step 5 – assemble:** $\tau = 200 \times 10^{-3}$

$\tau = 0.2$ s.

**Final Answer:** $\tau = 0.2$ s $\Rightarrow \boxed{\text{D}}$

**Answer: (D)** Go Back to Q7

## Q8.

**Solution**

**Concept – charging transient of an $RC$ circuit:** $v_C(t) = V_f\left(1 - e^{-t/\tau}\right)$, where $V_f$ is the final value.

**Step 1 – set $t = \tau$ (one time constant):** $v_C(\tau) = V_f\left(1 - e^{-1}\right)$.

**Step 2 – evaluate $e^{-1}$:** $e^{-1} \approx 0.368$.

**Step 3 – compute the bracket:** $1 - 0.368 = 0.632$.

**Step 4 – express as a percentage:** $v_C(\tau) = 0.632\, V_f = 63.2\%$ of the final value.

**Why the other options are wrong:**

- A, $37\%$: is the *remaining* fraction during discharge, $e^{-1}$.
- B, $100\%$: is only reached after about $5\tau$.
- C, $50\%$: corresponds to $t \approx 0.69\tau$, not one time constant.

**Final Answer:** $63.2\% \Rightarrow \boxed{\text{D}}$

**Answer: (D)** Go Back to Q8

## Q9.

**Solution**

**Concept – discharging transient of an $RC$ circuit:** $v_C(t) = V_0\, e^{-t/\tau}$, where $V_0$ is the initial voltage.

**Step 1 – list the data:** $V_0 = 10$ V, $\tau = 0.2$ s, $t = 0.2$ s.

**Step 2 – form the exponent:** $\dfrac{t}{\tau} = \dfrac{0.2}{0.2} = 1.$

**Step 3 – substitute:** $v_C = 10\, e^{-1}$

**Step 4 – evaluate $e^{-1}$:** $e^{-1} \approx 0.368$

**Step 5 – multiply:** $v_C = 10 \times 0.368$

$v_C \approx 3.7$ V.

**Why the other options are wrong:**

- A, $6.3$ V: is $10(1 - e^{-1})$, the *charging* value, not discharge.
- B, $10$ V: is the initial value, before any decay.
- D, $0$ V: is reached only after many time constants.

**Final Answer:** $v_C \approx 3.7$ V $\Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q9

## Q10.

**Solution**

**Concept – $s$-domain impedance of circuit elements:** In the Laplace domain each element has a characteristic impedance.

**Step 1 – recall the standard forms:** Resistor $\to R$; capacitor $\to 1/(sC)$; inductor $\to sL$.

**Step 2 – pick the inductor:** For an inductor $L$, the voltage-current relation $v = L\, di/dt$ transforms to $V(s) = sL\, I(s)$, so the impedance is $Z_L = sL$.

**Why the other options are wrong:**

- A, $1/(sL)$: is the admittance of the inductor, not its impedance.
- B, $sC$: is the admittance of a capacitor.
- D, $R$: is a resistor's impedance.

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

Answer: (C) Go Back to Q10

## Q11.

### Solution

**Concept – the capacitor's current-voltage law:** The charge on a capacitor is $q = Cv$, and current is the rate of change of charge.

**Step 1 – start from the charge relation:** $q = C\,v$.

**Step 2 – differentiate with respect to time:** $\dfrac{dq}{dt} = C\dfrac{dv}{dt}$ (with $C$ constant).

**Step 3 – identify the current:** Since $i = dq/dt$, we get $i = C\dfrac{dv}{dt}$.

**Why the other options are wrong:**

- B, $v = L\,di/dt$: is the inductor law, not the capacitor law.
- C, $i = v/R$: is Ohm's law for a resistor.
- D, $i = Cv$: is dimensionally wrong; current depends on the *rate of change* of $v$, not $v$ itself.

**Final Answer:** $i = C\,dv/dt \Rightarrow \boxed{\text{A}}$

**Answer: (A)** Go Back to Q11

## Q12.

### Solution

**Concept – resistive voltage divider:** $V_o = V_{in} \cdot \dfrac{R_2}{R_1 + R_2}$.

**Step 1 – list the data:** $V_{in} = 15$ V, $R_1 = 3$ k$\Omega$, $R_2 = 6$ k$\Omega$.

**Step 2 – add the series resistances:** $R_1 + R_2 = 3 + 6 = 9$ k$\Omega$.

**Step 3 – form the divider ratio:** $\dfrac{R_2}{R_1 + R_2} = \dfrac{6}{9} = \dfrac{2}{3}$.

**Step 4 – multiply by the source:** $V_o = 15 \times \dfrac{2}{3}$

$V_o = 10$ V.

**Why the other options are wrong:**

- A, 5 V: is the drop across $R_1$, not $R_2$.
- C, 7.5 V: would need equal resistors.
- D, 15 V: is the full source voltage.

**Final Answer:** $V_o = 10 \text{ V} \Rightarrow \boxed{\text{B}}$

**Answer: (B)** Go Back to Q12

## Q13.

**Solution**

**Concept – resistors in parallel:** $R_{eq} = \dfrac{R_1R_2}{R_1 + R_2}$.

**Step 1 – list the data:** $R_1 = 6\ \Omega$, $R_2 = 3\ \Omega$.

**Step 2 – form the product:** $R_1R_2 = 6 \times 3 = 18$.

**Step 3 – form the sum:** $R_1 + R_2 = 6 + 3 = 9$.

**Step 4 – divide:** $R_{eq} = \dfrac{18}{9}$

$R_{eq} = 2\ \Omega$.

**Why the other options are wrong:**

- A, $9\ \Omega$: is the *series* sum, not the parallel value.
- B, $18\ \Omega$: is only the product $R_1R_2$.
- C, $4.5\ \Omega$: would be the average, not the parallel combination.

**Final Answer:** $R_{eq} = 2\ \Omega \Rightarrow \boxed{\text{D}}$

**Answer: (D)** Go Back to Q13

## Q14.

**Solution**

**Concept – DC (average) output of a half-wave rectifier:** For an ideal half-wave rectifier the average of the output over a full cycle is $V_{dc} = \dfrac{V_m}{\pi}$.

**Step 1 – list the data:** $V_m = 10$ V.

**Step 2 – substitute into the formula:** $V_{dc} = \dfrac{10}{\pi}$

**Step 3 – use $\pi \approx 3.1416$:** $V_{dc} = \dfrac{10}{3.1416}$

**Step 4 – divide:** $V_{dc} \approx 3.18$ V.

**Why the other options are wrong:**

- A, $6.37$ V: is the *full-wave* average $2V_m/\pi$.
- B, $10$ V: is the peak value, not the average.
- D, $5$ V: is $V_m/2$, which is not the rectified average.

**Final Answer:** $V_{dc} \approx 3.18\text{ V} \Rightarrow \boxed{\text{C}}$

**Answer: (C)** Go Back to Q14

## Q15.

**Solution**

**Concept – DC (average) output of a full-wave rectifier:** A full-wave rectifier inverts the negative half, doubling the average to $V_{dc} = \dfrac{2V_m}{\pi}$.

**Step 1 – list the data:** $V_m = 10$ V.

**Step 2 – substitute:** $V_{dc} = \dfrac{2 \times 10}{\pi} = \dfrac{20}{\pi}$

**Step 3 – use $\pi \approx 3.1416$:** $V_{dc} = \dfrac{20}{3.1416}$

**Step 4 – divide:** $V_{dc} \approx 6.37$ V.

**Why the other options are wrong:**

- A, $3.18$ V: is the *half-wave* average $V_m/\pi$.
- B, $10$ V: is the peak, not the average.
- D, $5$ V: is $V_m/2$, unrelated to the rectified mean.

**Final Answer:** $V_{dc} \approx 6.37$ V $\Rightarrow \boxed{\text{C}}$

**Answer: (C)** Go Back to Q15

## Q16.

**Solution**

**Concept – biased diode clipper:** The diode conducts and clamps the output once the input exceeds the reference battery voltage, so the output is limited at that level.

**Step 1 – identify the clip level:** The reference battery is $3$ V, so the diode begins to conduct when the input tries to rise above $+3$ V.

**Step 2 – describe the clamped output:** Once conducting, the diode holds the output at $+3$ V; the input peaks above this level are "clipped off".

**Step 3 – state the maximum output:** Therefore the most positive value the output can reach is $+3$ V, even though the input peaks at $+10$ V.

**Why the other options are wrong:**

- A, $+10$ V: is the unclipped input peak.
- C, $-3$ V: has the wrong polarity; this clipper limits the positive side.
- D, $0$ V: would apply only if the reference were $0$ V.

**Final Answer:** output limited to $+3$ V $\Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q16

## Q17.

**Solution**

**Concept – exclusive-OR (XOR) logic:** An XOR output is HIGH only when its two inputs *differ*; when the inputs are equal, the output is LOW.

**Step 1 – write the XOR truth relation:** $Y = A \oplus B$, so $Y = 1$ if $A \neq B$ and $Y = 0$ if $A = B$.

**Step 2 – apply the given inputs:** $A = 1$ and $B = 1$, so the two inputs are equal.

**Step 3 – read the output:** Equal inputs give $Y = 0$.

**Why the other options are wrong:**

- A, 1: would require the inputs to differ.
- C, high impedance: is a tri-state condition, not an XOR output.
- D, undefined: an XOR is fully defined for all inputs.

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

Answer: (B) Go Back to Q17

## Q18.

**Solution**

**Concept – bits and distinct levels:** $n$ bits can encode $2^n$ distinct levels, so the required $n$ satisfies $2^n \geq$ number of levels.

**Step 1 – state the requirement:** We need $2^n \geq 1024$.

**Step 2 – recognise the power of two:** $2^{10} = 1024$.

**Step 3 – solve for $n$:** $n = 10$ bits are exactly sufficient.

**Why the other options are wrong:**

- B, $8$ bits: give only $2^8 = 256$ levels.
- C, $12$ bits: give $4096$ levels, more than needed (not the *minimum*).
- D, $1024$: is the number of levels, not the number of bits.

**Final Answer:** $n = 10$ bits $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q18

## Q19.

### Solution

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

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

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

**Step 3 – divide:** Resolution $= \dfrac{4.096}{4096}$

**Step 4 – evaluate:** Resolution $= 0.001$ V $= 1$ mV.

**Why the other options are wrong:**

- A, $4$ mV: uses $2^{10}$ instead of $2^{12}$.
- B, $0.5$ mV: would need $8192$ steps ($13$ bits).
- D, $2$ mV: uses $2^{11}$ steps.

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

**Answer: (C)** Go Back to Q19

## Q20.

### Solution

**Concept – the Pt100 platinum RTD:** An RTD's number in the name states its nominal resistance at $0$ °C.

**Step 1 – read the curve:** The transfer curve is nearly linear with a positive slope (positive temperature coefficient), and its intercept at $0$ °C is marked $100\ \Omega$.

**Step 2 – interpret the "Pt100" label:** "Pt" denotes platinum and "100" denotes $100\ \Omega$ at $0$ °C.

**Step 3 – state the nominal resistance:** The nominal resistance at $0$ °C is therefore $100\ \Omega$.

**Why the other options are wrong:**

- B, $1000\ \Omega$: is a Pt1000 element.
- C and D, $50\ \Omega$ / $10\ \Omega$: are not the standard Pt100 value.

**Final Answer:** $100\ \Omega$ at $0$ °C $\Rightarrow \boxed{\text{A}}$

**Answer: (A)** Go Back to Q20

## Q21.

**Solution**

**Concept – linear RTD model:** $R = R_0(1 + \alpha T)$.

**Step 1 – list the data:** $R_0 = 100\ \Omega$, $\alpha = 0.00385\ °\text{C}^{-1}$, $T = 100\ °\text{C}$.

**Step 2 – form the product $\alpha T$:** $\alpha T = 0.00385 \times 100 = 0.385$.

**Step 3 – add 1:** $1 + \alpha T = 1 + 0.385 = 1.385$.

**Step 4 – multiply by $R_0$:** $R = 100 \times 1.385$

$R = 138.5\ \Omega$.

**Why the other options are wrong:**

- A, $100\ \Omega$: ignores the temperature rise.
- B, $385\ \Omega$: forgets the "1+" and mis-scales.
- C, $103.85\ \Omega$: uses $T = 10\ °\text{C}$ instead of $100\ °\text{C}$.

**Final Answer:** $R = 138.5\ \Omega \Rightarrow \boxed{\text{D}}$

**Answer: (D)** Go Back to Q21

## Q22.

**Solution**

**Concept – thermistor self-heating:** The dissipation constant $\delta$ (mW/°C) links the electrical power dissipated to the temperature rise above ambient: $\Delta T = \dfrac{P}{\delta}$.

**Step 1 – list the data:** $\delta = 2$ mW/°C, $P = 4$ mW.

**Step 2 – apply the relation:** $\Delta T = \dfrac{P}{\delta}$

**Step 3 – substitute:** $\Delta T = \dfrac{4\ \text{mW}}{2\ \text{mW/°C}}$

**Step 4 – divide:** $\Delta T = 2\ °\text{C}$.

**Why the other options are wrong:**

- A, $0.5\ °\text{C}$: inverts the ratio ($\delta/P$).
- B, $8\ °\text{C}$: multiplies instead of dividing.
- D, $4\ °\text{C}$: quotes the power value, not the temperature rise.

**Final Answer:** $\Delta T = 2\ °\text{C} \Rightarrow \boxed{\text{C}}$

**Answer: (C)** Go Back to Q22

## Q23.

**Solution**

**Concept – Wheatstone bridge balance:** At balance the ratios of the two arms are equal: $\frac{R_1}{R_2} = \frac{R_3}{R_4}$.

**Step 1 – list the data:** $R_1 = 200\ \Omega$, $R_2 = 400\ \Omega$, $R_3 = 300\ \Omega$.

**Step 2 – rearrange for $R_4$:** $R_4 = R_3 \cdot \frac{R_2}{R_1}$.

**Step 3 – substitute:** $R_4 = 300 \times \frac{400}{200}$

**Step 4 – simplify the ratio:** $\frac{400}{200} = 2$

**Step 5 – multiply:** $R_4 = 300 \times 2 = 600\ \Omega$.

**Why the other options are wrong:**

- A, $150\ \Omega$: uses $R_1/R_2$ instead of $R_2/R_1$.
- C, $450\ \Omega$: adds a wrong proportion.
- D, $200\ \Omega$: ignores the $2:1$ arm ratio.

**Final Answer:** $R_4 = 600\ \Omega \Rightarrow \boxed{\text{B}}$

**Answer: (B)** Go Back to Q23

## Q24.

**Solution**

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

**Step 1 – list the data:** $A_d = 2000$, $A_c = 0.2$.

**Step 2 – form the ratio:** $\frac{A_d}{A_c} = \frac{2000}{0.2} = 10000$.

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

**Step 4 – multiply by 20:** $\text{CMRR}_{\text{dB}} = 20 \times 4 = 80$ dB.

**Why the other options are wrong:**

- B, 40 dB: corresponds to a ratio of only 100.
- C, 100 dB: corresponds to a ratio of $10^5$.
- D, 60 dB: corresponds to a ratio of 1000.

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

**Answer: (A)** Go Back to Q24

## Q25.

### Solution

**Concept – the piezoelectric transducer:** A piezoelectric crystal produces an electric charge in response to applied mechanical stress, but the charge leaks away for a steady load, so it responds only to *changing* (dynamic) inputs.

**Step 1 – match the requirement:** We need a sensor for rapidly varying pressure or heart sounds, i.e. dynamic signals, that directly gives an electrical output from mechanical stress.

**Step 2 – identify the device:** The piezoelectric crystal fits: it converts dynamic force/pressure into charge with a very fast response, and is widely used in phonocardiography and ultrasound transducers.

**Step 3 – note its limitation:** Because the generated charge decays through any finite input resistance, it cannot hold a true static (DC) reading, which matches the question.

**Why the other options are wrong:**

- A, RTD: senses temperature, not pressure.
- B, LVDT: measures displacement and needs AC excitation; it is not the direct dynamic-pressure element described.
- D, thermocouple: senses a temperature difference, not mechanical stress.

**Final Answer:** piezoelectric crystal $\Rightarrow \boxed{\text{C}}$

**Answer: (C)** Go Back to Q25

## Q26.

### Solution

**Concept – the Nyquist sampling criterion:** To avoid aliasing, the sampling frequency must exceed twice the highest frequency present: $f_s > 2f_{max}$.

**Step 1 – identify the highest frequency:** The diagnostic ECG band extends to $f_{max} = 150$ Hz.

**Step 2 – apply the criterion:** $f_s > 2 \times 150$

**Step 3 – evaluate:** $f_s > 300$ Hz.

**Step 4 – state the minimum:** The minimum (Nyquist) sampling frequency is $300$ Hz (practical ECG recorders sample well above this, e.g. $500$ Hz).

**Why the other options are wrong:**

- A, 150 Hz: equals $f_{max}$ and would alias badly.
- B, 1500 Hz: is valid but far above the *minimum*.
- C, 75 Hz: is below $f_{max}$ and grossly undersamples.

**Final Answer:** $f_s = 300$ Hz $\Rightarrow \boxed{\text{D}}$

**Answer: (D)** Go Back to Q26

## Q27.

### Solution

**Concept – removing ECG baseline wander:** Baseline wander is a very-low-frequency artefact (below about 0.5 Hz). To reject low frequencies while passing the ECG, a high-pass filter is used.

**Step 1 – characterise the artefact:** Respiration and slow electrode drift produce components below $\sim 0.5$ Hz.

**Step 2 – read the magnitude response:** The sketch shows near-zero gain at DC and low $f$, rising to unity above the cut-off, then flat – the signature of a high-pass filter.

**Step 3 – match to the requirement:** A high-pass filter with cut-off around 0.5 Hz removes the drift while preserving the ECG waves above it.

**Why the other options are wrong:**

- B, low-pass: would keep the drift and remove the higher ECG content.
- C, all-pass: changes only phase, not the drift amplitude.
- D, pure integrator: emphasises low frequencies, worsening the drift.

**Final Answer:** high-pass filter ($f_c \approx 0.5$ Hz) $\Rightarrow \boxed{\text{A}}$

**Answer: (A)** Go Back to Q27

## Q28.

### Solution

**Concept – suppressing high-frequency muscle noise:** Electromyographic (EMG) interference lies above the diagnostic ECG band, so a filter that passes low frequencies and rejects high ones is required.

**Step 1 – characterise the noise:** Muscle (EMG) noise is broadband and dominated by frequencies well above $\sim 150$ Hz.

**Step 2 – choose the filter type:** A low-pass filter with a cut-off around 100–150 Hz passes the ECG (including the QRS) and attenuates the higher-frequency muscle noise.

**Step 3 – justify preserving the QRS:** The essential QRS energy lies below $\sim 100$ Hz, so a low-pass cut-off near 150 Hz keeps the QRS intact while removing much of the muscle noise.

**Why the other options are wrong:**

- A, high-pass: would pass the very noise we wish to remove.
- B, notch at 50 Hz: targets power-line hum, a single narrow line, not broad-band EMG.
- C, differentiator: amplifies high-frequency noise.

**Final Answer:** low-pass filter ($f_c \approx 100$–$150$ Hz) $\Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q28

## Q29.

### Solution

**Concept – removing power-line interference:** Mains hum is a single narrow line at 50 Hz. A filter that rejects one narrow band while passing everything else is a notch (band-reject) filter.

**Step 1 – read the magnitude response:** The response is flat at unity except for a single deep, narrow dip exactly at 50 Hz.

**Step 2 – identify the filter:** This is the defining shape of a notch (band-reject) filter centred at 50 Hz.

**Step 3 – match to the task:** Because only the 50 Hz component is removed, the rest of the ECG spectrum is preserved, which is exactly what is wanted.

**Why the other options are wrong:**

- B, low-pass: would also remove ECG content above 50 Hz.
- C, high-pass: would remove content below 50 Hz.
- D, all-pass: does not attenuate the 50 Hz line at all.

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

Answer: (A) Go Back to Q29

## Q30.

**Solution**

**Concept – signal-to-noise ratio in dB:** For amplitude (voltage) ratios, $\text{SNR}_{\text{dB}} = 20\log_{10}\left(\dfrac{V_s}{V_n}\right)$.

**Step 1 – list the data:** $V_s = 2$ V, $V_n = 0.02$ V.

**Step 2 – form the ratio:** $\dfrac{V_s}{V_n} = \dfrac{2}{0.02} = 100$.

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

**Step 4 – multiply by** $20$**:** $\text{SNR}_{\text{dB}} = 20 \times 2 = 40$ dB.

**Why the other options are wrong:**

- A, $20$ dB: corresponds to a ratio of $10$.
- C, $60$ dB: corresponds to a ratio of $1000$.
- D, $80$ dB: corresponds to a ratio of $10000$.

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

**Answer: (B)** Go Back to Q30

## Q31.

**Solution**

**Concept – X-ray production in the tube:** X-rays are generated where fast electrons are suddenly stopped in a dense, high-atomic-number metal target.

**Step 1 – trace the electron path:** The heated cathode filament emits electrons, which are accelerated across the tube by the high voltage.

**Step 2 – identify the impact site:** The electrons slam into the anode (a tungsten target), where their rapid deceleration produces bremsstrahlung and characteristic X-rays.

**Step 3 – name the element:** Thus X-rays originate at the anode (metal target).

**Why the other options are wrong:**

- B, cathode filament: only emits the electrons; it does not produce the X-rays.
- C, glass envelope: merely maintains the vacuum.
- D, collimator: shapes the emerging beam; it does not create X-rays.

**Final Answer:** anode (metal target) $\Rightarrow \boxed{\text{A}}$

**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:** $\mu = 0.1$ cm$^{-1}$, $x = 10$ cm.

**Step 2 – form the exponent:** $\mu x = 0.1 \times 10 = 1$.

**Step 3 – substitute:** $\dfrac{I}{I_0} = e^{-1}$

**Step 4 – evaluate $e^{-1}$:** $e^{-1} \approx 0.368 \approx 0.37$.

**Why the other options are wrong:**

- A, $0.90$: would apply for $\mu x \approx 0.1$.
- B, $0.10$: corresponds to $\mu x \approx 2.3$.
- C, $0.50$: corresponds to $\mu x = \ln 2 \approx 0.69$.

**Final Answer:** $I/I_0 \approx 0.37 \Rightarrow \boxed{\text{D}}$

**Answer: (D)** Go Back to Q32

## Q33.

**Solution**

**Concept – half-value layer:** HVL $= \dfrac{\ln 2}{\mu}$, the thickness that halves the beam intensity.

**Step 1 – list the data:** $\mu = 0.693$ cm$^{-1}$, and $\ln 2 \approx 0.693$.

**Step 2 – substitute:** HVL $= \dfrac{0.693}{0.693}$

**Step 3 – divide:** HVL $= 1$ cm.

**Step 4 – check by attenuation:** $e^{-\mu \cdot \mathrm{HVL}} = e^{-0.693} \approx 0.5$, confirming the intensity is halved.

**Why the other options are wrong:**

- A, $0.693$ cm: mistakes $1/\mu$-type scaling and drops the $\ln 2$ cancellation.
- B, $2$ cm: is two half-value layers ($I/I_0 = 1/4$).
- C, $0.5$ cm: would halve the intensity only if $\mu$ were doubled.

**Final Answer:** HVL $= 1$ cm $\Rightarrow \boxed{\text{D}}$

**Answer: (D)** Go Back to Q33

## Q34.

### Solution

**Concept – radiographic contrast:** On a plain film, a structure appears bright when it absorbs (attenuates) more X-rays, i.e. when it has a larger linear attenuation coefficient.

**Step 1 – compare bone and soft tissue:** Bone contains calcium and phosphorus (higher effective atomic number) and is denser than soft tissue.

**Step 2 – link to attenuation:** Higher atomic number and density give bone a much larger linear attenuation coefficient $\mu$ for diagnostic X-rays.

**Step 3 – explain the image:** Bone therefore absorbs more of the beam, fewer X-rays reach the detector behind it, and it prints bright (white) against darker soft tissue.

**Why the other options are wrong:**

- B, speed of sound: governs ultrasound, not X-ray contrast.
- C, proton density: governs MRI signal, not radiography.
- D, electrical conductivity: is irrelevant to X-ray attenuation.

**Final Answer:** larger linear attenuation coefficient $\Rightarrow \boxed{\text{A}}$

**Answer: (A)** Go Back to Q34

## Q35.

### Solution

**Concept – CT image reconstruction:** CT collects many one-dimensional projections at different angles and reconstructs the cross-section from them.

**Step 1 – recall the reconstruction problem:** Recovering the image from its projections is the inverse Radon transform.

**Step 2 – name the classical method:** The standard practical solution is filtered back-projection: each projection is convolved with a ramp filter and then smeared (back-projected) across the image plane.

**Step 3 – confirm the choice:** Filtered back-projection is the algorithm classically used in clinical CT scanners for this purpose.

**Why the other options are wrong:**

- A, FFT of the raw radiograph: is not by itself the CT reconstruction step.
- C, region growing: is an image-segmentation method.

- D, histogram equalisation: is a contrast-enhancement step, not reconstruction.

**Final Answer:** filtered back-projection $\Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q35

## Q36.

### Solution

**Concept – static equilibrium of the forearm lever:** For rotational equilibrium about the elbow, the anticlockwise muscle moment equals the clockwise load moment: $F_m \cdot d_m = W \cdot d_W$.

**Step 1 – list the data:** $W = 60$ N at $d_W = 32$ cm; $F_m$ at $d_m = 4$ cm.

**Step 2 – write the moment balance:** $F_m \cdot d_m = W \cdot d_W$.

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

**Step 4 – substitute (the cm cancel):** $F_m = \dfrac{60 \times 32}{4}$

**Step 5 – compute the numerator:** $60 \times 32 = 1920$.

**Step 6 – divide:** $F_m = \dfrac{1920}{4} = 480$ N.

**Why the other options are wrong:**

- A, $60$ N: ignores the lever-arm ratio.
- B, $240$ N: uses a wrong distance ratio.
- C, $7.5$ N: inverts the ratio of arms.

**Final Answer:** $F_m = 480$ N $\Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q36

## Q37.

### Solution

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

**Step 1 – list the data in base units:** $F = 4000$ N, $A = 200$ mm$^2 = 200 \times 10^{-6}$ m$^2 = 2 \times 10^{-4}$ 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 $\sigma = 2000 \times 10^4 = 2 \times 10^7$ Pa.

**Step 5 – convert to MPa:** $\sigma = 2 \times 10^7$ Pa $= 20$ MPa.

**Why the other options are wrong:**

- A, 2 MPa: is a factor of 10 too small (unit slip).
- C, 200 MPa: is a factor of 10 too large.
- D, 0.2 MPa: mishandles the area conversion.

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

**Answer: (B)** Go Back to Q37

## Q38.

**Solution**

**Concept – phases of the gait cycle:** The gait cycle is divided into a stance phase (foot on the ground) and a swing phase (foot in the air).

**Step 1 – define stance:** The stance phase is the part of the cycle during which the foot is in contact with the ground and supporting body weight.

**Step 2 – match the description:** The question describes exactly this weight-bearing, ground-contact interval, which is the stance phase.

**Why the other options are wrong:**

- B, swing phase: is when the foot is off the ground and advancing.
- C, double-float phase: is a running feature (both feet airborne), absent in normal walking.
- D, recovery phase: is not a standard gait-cycle term.

**Final Answer:** stance phase $\Rightarrow \boxed{\text{A}}$

**Answer: (A)** Go Back to Q38

## Q39.

### Solution

**Concept – stance/swing split in normal gait:** In normal walking the two phases do not share the cycle equally; stance dominates.

**Step 1 – recall the standard proportions:** Stance phase occupies about $60\%$ of the gait cycle and swing about $40\%$.

**Step 2 – select the stance value:** Therefore the stance phase is approximately $60\%$ of the cycle.

**Step 3 – note the overlap:** The extra stance time (beyond a $50/50$ split) corresponds to the two periods of double support, when both feet are on the ground.

**Why the other options are wrong:**

- A, $10\%$: is far too small.
- B, $100\%$: would mean the foot never leaves the ground.
- C, $40\%$: is the swing-phase fraction, not stance.

**Final Answer:** stance $\approx 60\% \Rightarrow \boxed{\text{D}}$

**Answer: (D)** Go Back to Q39

## Q40.

### Solution

**Concept – Hooke's law (axial strain):** $\varepsilon = \dfrac{\sigma}{E}$.

**Step 1 – list the data in base units:** $\sigma = 40$ MPa $= 40 \times 10^6$ Pa, $E = 20$ GPa $= 20 \times 10^9$ Pa.

**Step 2 – substitute:** $\varepsilon = \dfrac{40 \times 10^6}{20 \times 10^9}$

**Step 3 – divide the coefficients:** $\dfrac{40}{20} = 2$.

**Step 4 – combine the powers of ten:** $\dfrac{10^6}{10^9} = 10^{-3}$.

**Step 5 – assemble:** $\varepsilon = 2 \times 10^{-3} = 0.002$.

**Why the other options are wrong:**

- A, $0.02$: is ten times too large (power-of-ten slip).
- C, $0.2$: is a hundred times too large.
- D, $0.0002$: is ten times too small.

**Final Answer:** $\varepsilon = 0.002 \Rightarrow \boxed{\text{B}}$

**Answer: (B)** Go Back to Q40

## Q41.

**Solution**

**Concept – bearing material in a hip prosthesis:** The acetabular cup needs a tough, low-friction, wear-resistant, bio-inert polymer to run against a hard metal or ceramic head.

**Step 1 – state the requirement:** The socket surface must have low friction and high wear resistance while being biocompatible.

**Step 2 – identify the material:** Ultra-high-molecular-weight polyethylene (UHMWPE) is the standard cup bearing material, articulating against a CoCr or ceramic femoral head.

**Why the other options are wrong:**

- B, mild steel: corrodes in the body and is not used for bearings.
- C, copper: is toxic and reactive in tissue.
- D, magnesium: degrades and corrodes rapidly; not a bearing surface.

**Final Answer:** UHMWPE $\Rightarrow \boxed{\text{A}}$

**Answer: (A)** Go Back to Q41

## Q42.

**Solution**

**Concept – the three PID terms:** $u = K_p e + K_i \int e\,dt + K_d \dfrac{de}{dt}$; each term acts on the error differently.

**Step 1 – interpret the derivative term:** The term $K_d\, de/dt$ responds to the *rate of change* of the error, effectively predicting where the error is heading.

**Step 2 – state its effect:** By reacting early to fast changes, the derivative action adds damping, reduces overshoot and speeds up the transient settling.

**Step 3 – select the answer:** Hence the anticipatory, transient-improving term is the derivative term.

**Why the other options are wrong:**

- A, integral term: removes steady-state error but tends to slow the response and add overshoot.

- C, proportional term: acts on the present error only, with no anticipation.
- D, bias term: is a constant offset, not part of the standard PID dynamics.

**Final Answer:** derivative term $\Rightarrow \boxed{\text{B}}$

**Answer: (B)** Go Back to Q42

## Q43.

### Solution

**Concept – eliminating steady-state error:** Steady-state error is removed by a term that keeps acting as long as any error persists.

**Step 1 – interpret the integral term:** $K_i \int e\, dt$ accumulates the error over time; its output keeps growing while any error remains.

**Step 2 – state its effect:** This accumulation forces the steady-state error to zero, because the controller output only stops changing when the error is exactly zero.

**Step 3 – select the answer:** Therefore the integral term is responsible for eliminating steady-state error.

**Why the other options are wrong:**

- A, proportional term: alone leaves a finite steady-state offset.
- B, derivative term: responds only to change and is zero at steady state.
- D, feed-forward term: is not one of the three PID feedback terms.

**Final Answer:** integral term $\Rightarrow \boxed{\text{C}}$

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

## Q44.

### Solution

**Concept – time constant of a first-order transfer function:** Writing the denominator in the standard form $\tau s + 1$, the coefficient of $s$ is the time constant $\tau$.

**Step 1 – read the transfer function:** $\dfrac{Y(s)}{X(s)} = \dfrac{5}{4s+1}$.

**Step 2 – compare with $\dfrac{K}{\tau s + 1}$:** The denominator $4s + 1$ matches $\tau s + 1$ with the coefficient of $s$ equal to $4$.

**Step 3 – identify $\tau$:** $\tau = 4$ s. (The numerator $5$ is the DC gain $K$ and does not affect the time constant.)

**Why the other options are wrong:**

- A, $5$ s: mistakes the gain $K$ for the time constant.
- C, $0.25$ s: is the pole magnitude $1/\tau$, not $\tau$.
- D, $1$ s: ignores the coefficient of $s$.

**Final Answer:** $\tau = 4$ s $\Rightarrow \boxed{\text{B}}$

**Answer: (B)** Go Back to Q44

## Q45.

### Solution

**Concept – system type:** The "type" of a system equals the number of poles of the open-loop transfer function at the origin ($s = 0$), i.e. the number of pure integrators in the forward path.

**Step 1 – read the open-loop function:** $G(s) = \dfrac{10}{s(s+2)}$.

**Step 2 – count the poles at the origin:** The factor $s$ in the denominator gives exactly one pole at $s = 0$; the factor $(s + 2)$ gives a pole at $s = -2$, not at the origin.

**Step 3 – state the type:** One pole at the origin $\Rightarrow$ Type 1 system.

**Why the other options are wrong:**

- A, Type 0: would need no pole at the origin.
- C, Type 2: would need two poles at the origin ($s^2$).
- D, Type 3: would need three poles at the origin.

**Final Answer:** Type 1 system $\Rightarrow \boxed{\text{B}}$

**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:** $C = 50\ \mu\text{F} = 50 \times 10^{-6}$ F, $V = 4000$ V.

**Step 2 – square the voltage:** $V^2 = (4000)^2 = 16 \times 10^6\ \text{V}^2$.

**Step 3 – multiply by the capacitance:** $CV^2 = 50 \times 10^{-6} \times 16 \times 10^6$.

**Step 4 – combine coefficients and powers of ten:** $50 \times 16 = 800$ and $10^{-6} \times 10^6 = 1$, so $CV^2 = 800$.

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

$E = 400$ J.

**Why the other options are wrong:**

- A, 100 J: drops a factor in the arithmetic.
- B, 200 J: halves the result once too often.
- C, 800 J: omits the factor $\frac{1}{2}$.

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

**Answer: (D)** **Go Back to Q46**

# Answer Key

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