GATE Biomedical Engineering

Sample Paper – 7

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 haematocrit (packed-cell volume) of a blood sample is the fraction of whole-blood volume occupied by the red cells after centrifugation. For a healthy adult male this value is nearest to: **[1 mark]**

(A) 25%

(B) 45%

(C) 75%

(D) 5%

Q2. The formed element of blood chiefly responsible for carrying oxygen from the lungs to the tissues, by means of the haemoglobin it contains, is the: **[1 mark]**

(A) platelet (thrombocyte)

(B) neutrophil

(C) erythrocyte (red blood cell)

(D) lymphocyte

Q3. The antibody-mediated (humoral) arm of the adaptive immune response is carried out mainly by the cells that mature into antibody-secreting plasma cells, namely the: **[1 mark]**

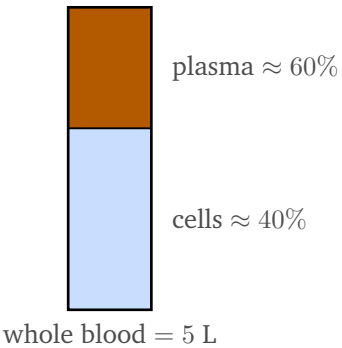
(A) cytotoxic T cells

(B) B lymphocytes

(C) erythrocytes

(D) platelets

Q4. A healthy adult has a total blood volume of about 5 L. The stacked column below shows that plasma makes up about 60% of whole blood and the cells about 40%. The volume occupied by plasma is nearest to: **[1 mark]**



(A) 3 L

(B) 2 L

(C) 5 L

(D) 0.4 L

Q5. During blood coagulation, a soluble plasma protein is enzymatically converted by thrombin into insoluble fibrin threads that trap cells and form the clot. That precursor plasma protein is: [1 mark]

(A) albumin

(B) fibrinogen

(C) haemoglobin

(D) immunoglobulin G

Q6. A person's red cells carry neither A nor B surface antigens, while the plasma contains both anti-A and anti-B antibodies. In the ABO system this person's blood group is: [1 mark]

(A) group O

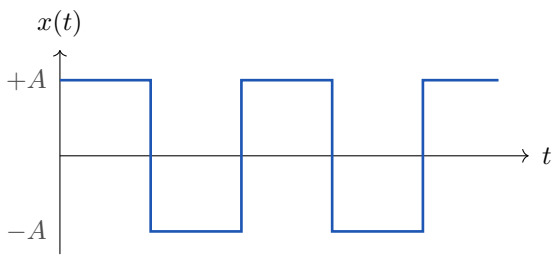
(B) group AB

(C) group A

(D) group B

Electric Circuits, Signals and Systems

Q7. The periodic waveform shown is an ideal, zero-mean square wave that is an odd function of time. Its trigonometric Fourier series contains: [1 mark]



(A) only even harmonics

(B) a DC term plus all harmonics

(C) only cosine terms

(D) only odd harmonics (sine terms), with no DC component

Q8. A periodic biomedical signal has a fundamental period of $T = 20$ ms. Its fundamental frequency $f_0 = 1/T$ is: **[1 mark]**

(A) 50 Hz

(B) 20 Hz

(C) 100 Hz

(D) 500 Hz

Q9. The trigonometric Fourier series of a periodic signal that is an *even* function of time ($x(-t) = x(t)$) contains: **[1 mark]**

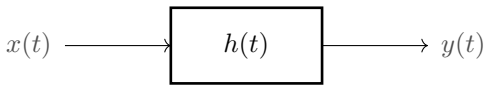
(A) only sine terms

(B) only cosine terms, together with a possible DC term

(C) only odd harmonics

(D) no DC component under any condition

Q10. For the linear time-invariant (LTI) system shown, with impulse response $h(t)$, the output $y(t)$ is obtained from the input $x(t)$ by: **[1 mark]**



(A) point-by-point multiplication of $x(t)$ and $h(t)$

(B) addition of $x(t)$ and $h(t)$

(C) differentiation of $x(t)$

(D) convolution of $x(t)$ with $h(t)$

Q11. A system whose output at any instant depends only on the value of the input at that same instant (and not on past or future inputs) is classified as: **[1 mark]**

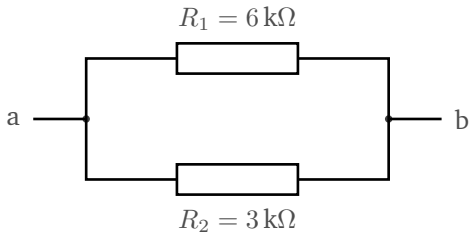
(A) dynamic (with memory)

(B) memoryless (static)

(C) unstable

(D) time-varying

Q12. Two resistors $R_1 = 6$ kΩ and $R_2 = 3$ kΩ are connected in parallel as shown. The equivalent resistance between the two nodes is: **[1 mark]**



(A) 9 kΩ

(B) 4.5 kΩ

(C) 2 kΩ

(D) 18 kΩ

Q13. For a real-valued periodic signal, the complex exponential Fourier-series coefficients c_n obey a symmetry relation. That relation is: **[1 mark]**

(A) $c_{-n} = c_n$

(B) $c_{-n} = -c_n$

(C) $c_n = 0$ for all $n < 0$

(D) $c_{-n} = c_n^*$ (conjugate symmetry)

Analog and Digital Electronics

Q14. The class of power amplifier in which the output device conducts for the entire 360° of the input signal cycle, giving the lowest distortion but a poor power efficiency, is: **[1 mark]**

(A) Class A

(B) Class B

(C) Class C

(D) Class D

Q15. The maximum theoretical collector-circuit efficiency of an ideal Class B push-pull power amplifier (sinusoidal drive, full output swing) is nearest to: [1 mark]

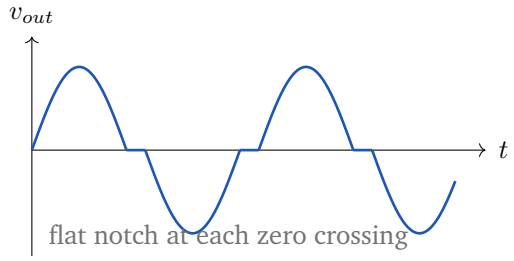
(A) 25%

(B) 50%

(C) 100%

(D) 78.5%

Q16. The output waveform of a Class B push-pull stage is sketched below. The flattening near each zero crossing, caused because both output transistors are momentarily off, is called: [1 mark]



(A) harmonic distortion only

(B) saturation distortion

(C) crossover distortion

(D) intermodulation distortion

Q17. A Class C amplifier conducts for much less than half of the input cycle. Because of this heavily clipped conduction it is used mainly as a: [1 mark]

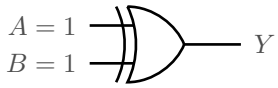
(A) high-fidelity audio output stage

(B) DC-coupled instrumentation amplifier

(C) tuned radio-frequency power amplifier

(D) linear class of biopotential amplifier

Q18. 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) high impedance

(C) undefined

(D) 0

Q19. A Class D (switching) power amplifier achieves very high efficiency compared with a linear amplifier because its output transistors are operated: **[1 mark]**

(A) continuously in the linear active region

(B) permanently at cutoff

(C) permanently in deep saturation

(D) as ON/OFF switches driven by a pulse-width-modulated signal

Sensors, Bioinstrumentation and Measurements

Q20. The electrode most widely used for recording surface biopotentials such as the ECG and EEG, chosen because it is essentially non-polarisable and has a stable, low half-cell potential, is the: **[1 mark]**

(A) silver–silver chloride (Ag/AgCl) electrode

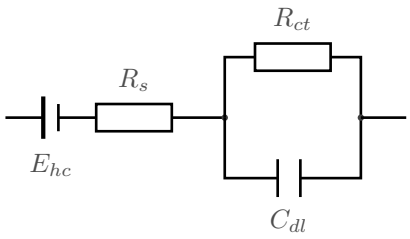
(B) pure platinum electrode

(C) stainless-steel needle electrode

(D) pure gold plate electrode

Q21. The electrode–electrolyte interface of a biopotential electrode is modelled by the equivalent circuit shown: a half-cell potential E_{hc} in series

with a series resistance R_s, together with a parallel combination of R_{ct} and C_{dl}. The parallel $R_{ct} \parallel C_{dl}$ pair chiefly represents: **[2 marks]**



(A) the inductance of the lead wire

(B) the input impedance of the amplifier

(C) the sweat-gland ducts of the skin only

(D) the double-layer capacitance and charge-transfer resistance at the metal–electrolyte interface

Q22. Two nominally identical Ag/AgCl electrodes are placed on a patient. One settles at a half-cell potential of $+0.223$ V and the other at $+0.213$ V. The differential offset (electrode) potential that the amplifier must tolerate is: **[2 marks]**

(A) 0.436 V

(B) 0.223 V

(C) 0.010 V (10 mV)

(D) 0.213 V

Q23. A perfectly polarisable electrode (for example a smooth platinum electrode) passes essentially no direct charge across its interface. At the interface it therefore behaves electrically predominantly like a: **[2 marks]**

(A) capacitor

(B) pure ohmic resistor

(C) ideal constant-voltage source

(D) pure inductor

Q24. To reduce motion artefact and lower the skin–electrode contact impedance when recording an ECG, standard clinical practice is to: [2 marks]

(A) shrink the electrode contact area toward zero

(B) remove all electrolyte and record through dry skin

(C) leave the outer (stratum corneum) skin layer untouched and use no gel

(D) lightly abrade the stratum corneum and apply a conductive electrolyte gel

Q25. A biopotential source of 2.0 mV has an electrode (source) resistance of 50 kΩ. It is connected to an amplifier whose input resistance is 950 kΩ. Treating this as a simple voltage divider, the voltage actually appearing at the amplifier input is: [2 marks]

(A) 2.0 mV

(B) 1.9 mV

(C) 0.1 mV

(D) 1.0 mV

Biomedical Signal Processing

Q26. A digital filter whose impulse response contains only a finite number of nonzero samples, and which uses no feedback of past output values, is called a: [2 marks]

(A) recursive IIR filter

(B) finite impulse response (FIR) filter

(C) passive analog filter

(D) all-pass recursive filter

Q27. A key advantage of an FIR digital filter over an IIR filter of comparable magnitude response is that the FIR filter can be designed to have: [2 marks]

(A) exactly linear phase (constant group delay)

(B) always fewer coefficients

(C) poles located outside the unit circle

(D) a guaranteed unstable response

Q28. A discrete-time filter has the difference equation $y[n] = x[n] - x[n-1]$ (a first difference). In terms of its frequency response, this filter acts as a: **[2 marks]**

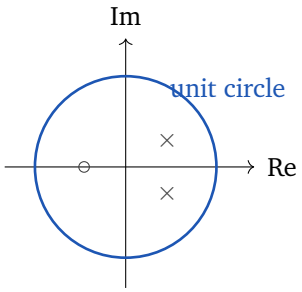
(A) low-pass filter

(B) all-pass filter

(C) narrow-band resonator

(D) high-pass (first-difference / differencing) filter

Q29. The pole–zero map of a causal recursive (IIR) digital filter is sketched on the z-plane below. For the filter to be both causal and stable, every pole must lie: **[2 marks]**



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

(B) outside the unit circle ($|z| > 1$)

(C) exactly on the unit circle ($|z| = 1$)

(D) only at the origin ($z = 0$)

Q30. A biosignal is sampled at $f_s = 8$ kHz and processed by a digital low-pass filter whose normalised cut-off frequency is 0.25 (expressed as a fraction of the sampling frequency). The equivalent analog cut-off frequency is: **[2 marks]**

(A) 4000 Hz

(B) 2000 Hz

(C) 1000 Hz

(D) 8000 Hz

Medical Imaging Systems

Q31. In Doppler ultrasound used to measure blood flow, the frequency shift of the returned echo arises because the sound is scattered from moving: [2 marks]

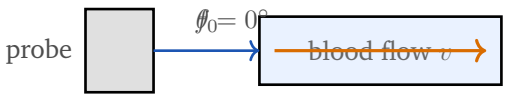
(A) bony interfaces

(B) red blood cells (moving scatterers in the blood)

(C) the transducer crystal itself

(D) stationary vessel walls

Q32. A continuous-wave Doppler probe with transmit frequency $f_0 = 5$ MHz insonates a blood vessel head-on, so the beam-to-flow angle is $\theta = 0^\circ$ (i.e. $\cos\theta = 1$). The blood velocity is $v = 0.5$ m/s and the speed of sound is $c = 1540$ m/s. Using $f_d = \dfrac{2 f_0 v \cos\theta}{c}$, the Doppler shift f_d is nearest to: [2 marks]



(A) 1.6 kHz

(B) 6.5 kHz

(C) 3.2 kHz

(D) 0.65 kHz

Q33. Compared with pulsed-wave (PW) Doppler, the principal limitation of continuous-wave (CW) Doppler in a vascular study is that CW Doppler: [2 marks]

(A) cannot measure high blood velocities

(B) needs a two-element transducer, which PW does not

(C) gives no depth (range) resolution, so it cannot localise the sampled vessel

(D) can never detect the direction of flow

Q34. The measured Doppler shift depends on the angle θ between the ultrasound beam and the direction of blood flow through $\cos\theta$. To obtain the largest (and most reliable) Doppler shift, the operator should keep θ: [2 marks]

(A) close to 0°, so the beam is nearly parallel to the flow

(B) exactly 90° to the flow

(C) exactly 180° and no other value

(D) irrelevant, because the shift does not depend on angle

Q35. A pulsed-wave Doppler system samples the returning signal once per transmitted pulse, so its pulse-repetition frequency acts as the sampling rate. With PRF $= 8$ kHz, the maximum Doppler shift it can measure without aliasing (the Nyquist limit) is: [2 marks]

(A) 4 kHz

(B) 8 kHz

(C) 16 kHz

(D) 2 kHz

Biomechanics and Biomaterials

Q36. In the two-element Windkessel model of the systemic arteries, the elastic reservoir action of the large arteries (their ability to store blood during systole and release it during diastole) is represented in the electrical analogue by a: [2 marks]

(A) series inductor

(B) constant-voltage source

(C) forward-biased diode

(D) capacitor (compliance) in parallel with a resistor

Q37. For the systemic circulation the resistance obeys $R = \dfrac{\Delta P}{Q}$. Taking a mean arterial pressure of 100 mmHg, a right-atrial pressure of about 0 mmHg and a cardiac output of $Q = 5$ L/min, the systemic vascular resistance is: **[2 marks]**

(A) 20 mmHg·min/L

(B) 500 mmHg·min/L

(C) 5 mmHg·min/L

(D) 0.05 mmHg·min/L

Q38. Arterial compliance is defined as $C = \dfrac{\Delta V}{\Delta P}$. If injecting $\Delta V = 2$ mL of blood into an arterial segment raises its pressure by $\Delta P = 40$ mmHg, the compliance of that segment is: **[2 marks]**

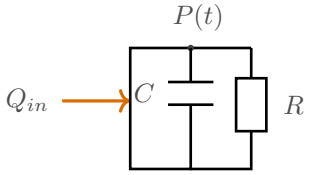
(A) 20 mL/mmHg

(B) 80 mL/mmHg

(C) 0.05 mL/mmHg

(D) 0.5 mL/mmHg

Q39. In the two-element Windkessel model the arterial compliance C and peripheral resistance R appear as the parallel network shown. During diastole, when the aortic valve is closed and there is no inflow, the aortic pressure $P(t)$ decays: **[2 marks]**



(A) linearly with time

(B) as an instantaneous step to zero

(C) exponentially, with time constant $\tau = RC$

(D) as a rising ramp

Q40. By Poiseuille's law the volumetric flow through a rigid tube is proportional to the fourth power of its radius, $Q \propto r^4$. If the radius of a blood vessel is reduced to one-half of its original value at constant driving pressure, the flow becomes: [2 marks]

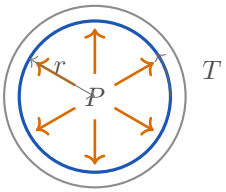
(A) one-half of the original flow

(B) one-sixteenth of the original flow

(C) one-quarter of the original flow

(D) one-eighth of the original flow

Q41. For a thin-walled cylindrical blood vessel, Laplace's law gives the circumferential wall tension per unit length as $T = P\,r$, where P is the transmural pressure and r the internal radius. For $P = 13000$ Pa (about 100 mmHg) and $r = 0.01$ m, the wall tension is: [2 marks]



(A) 1.3 N/m

(B) 13 N/m

(C) 130 N/m

(D) 1300 N/m

Control Systems and Medical Instrumentation

Q42. In a biotelemetry link, the amplified biological signal (for example an ECG) is used to vary the instantaneous frequency of an RF carrier before transmission, because this scheme is robust against amplitude noise. This modulation scheme is: [2 marks]

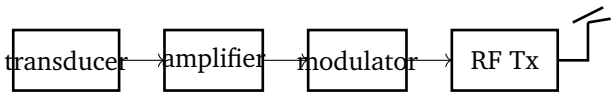
(A) amplitude modulation (AM)

(B) pulse-code modulation (PCM) only

(C) frequency modulation (FM)

(D) no modulation (baseband) transmission

Q43. The block diagram of a single-channel biotelemetry transmitter is shown. Reading it from the patient outward, the correct order of the signal chain is: **[2 marks]**



(A) antenna $\rightarrow$ modulator $\rightarrow$ amplifier $\rightarrow$ transducer

(B) modulator $\rightarrow$ transducer $\rightarrow$ amplifier $\rightarrow$ antenna

(C) amplifier $\rightarrow$ transducer $\rightarrow$ antenna $\rightarrow$ modulator

(D) transducer $\rightarrow$ amplifier $\rightarrow$ modulator $\rightarrow$ RF transmitter (antenna)

Q44. An implantable biotelemetry unit transmits at a carrier frequency of 400 MHz. Taking the speed of light as $c = 3 \times 10^8$ m/s, the free-space wavelength of this carrier is: **[2 marks]**

(A) 1.33 m

(B) 0.75 m

(C) 7.5 m

(D) 0.075 m

Q45. Compared with a wearable (on-body) telemetry unit, a fully implanted (in-body) biotelemetry device faces the additional key design constraint of: **[2 marks]**

(A) extremely low power consumption together with a biocompatible, hermetically sealed package

(B) a large mains-powered supply inside the body

(C) a mechanical cooling fan for the electronics

(D) a permanent external wired data connection

Q46. A negative-feedback closed-loop drug-infusion controller has a forward-path gain $G = 9$ and unity feedback ($H = 1$). Its closed-loop gain, $\frac{G}{1+GH}$, is: **[2 marks]**

(A) 9

(B) 0.9

(C) 0.1

(D) 10

Detailed Solutions

Q1.

Solution

Concept – haematocrit: The haematocrit is the volume fraction of whole blood taken up by red cells once the sample is spun down.

Step 1 – recall the normal range for an adult male: For a healthy adult male the packed-cell volume is about 40% to 50%.

Step 2 – pick the representative value: A single best value in this band is about 45%.

Why the other options are wrong:

- A, 25%: is anaemic (abnormally low).
- C, 75%: is far above any physiological value and would mean dangerously thick blood.
- D, 5%: is not survivable.

Final Answer: haematocrit $\approx 45\% \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q1

Q2.

Solution

Concept – oxygen transport in blood: Oxygen is carried bound to haemoglobin, which is packed inside one particular formed element.

Step 1 – identify the cell that contains haemoglobin: Haemoglobin is contained in the red blood cell (erythrocyte).

Step 2 – match function to cell: The erythrocyte binds oxygen at the lungs and releases it in the tissues.

Why the other options are wrong:

- A, platelet: is a fragment involved in clotting, not oxygen transport.
- B, neutrophil, and D, lymphocyte: are white cells that serve immune defence.

Final Answer: erythrocyte (red blood cell) $\Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q2

Q3.

Solution

Concept – humoral immunity: The adaptive immune response has a cell-mediated arm and an antibody (humoral) arm.

Step 1 – recall which lymphocyte makes antibodies: B lymphocytes, on activation, differentiate into plasma cells that secrete antibodies.

Step 2 – assign the humoral response: Antibody-mediated (humoral) immunity is therefore carried out by B lymphocytes.

Why the other options are wrong:

- A, cytotoxic T cells: mediate the cell-mediated response, killing infected cells directly.
- C, erythrocytes, and D, platelets: have no antibody-producing role.

Final Answer: B lymphocytes $\Rightarrow$ $\boxed{\text{B}}$

Answer: (B) Go Back to Q3

Q4.

Solution

Concept – plasma volume from blood composition: Plasma is the liquid fraction; if the cells occupy 40%, plasma occupies the remaining 60%.

Step 1 – list the data: Total blood volume $= 5$ L, plasma fraction $= 60\% = 0.60$.

Step 2 – multiply the total by the plasma fraction: $V_{plasma} = 0.60 \times 5$

Step 3 – evaluate: $V_{plasma} = 3$ L

Why the other options are wrong:

- B, 2 L: is the cell volume (40% of 5 L), not the plasma volume.
- C, 5 L: is the whole-blood volume.
- D, 0.4 L: confuses the fraction 0.4 with a volume.

Final Answer: $V_{plasma} = 3$ L $\Rightarrow$ $\boxed{\text{A}}$

Answer: (A) Go Back to Q4

Q5.

Solution

Concept – final step of the coagulation cascade: The clotting cascade ends by converting a soluble plasma protein into an insoluble fibrous mesh.

Step 1 – name the soluble precursor: The soluble plasma protein is fibrinogen (factor I).

Step 2 – identify the enzyme and product: Thrombin cleaves fibrinogen into fibrin, which polymerises into the clot mesh.

Why the other options are wrong:

- A, albumin: maintains oncotic pressure, not clotting.
- C, haemoglobin: is inside red cells and carries oxygen.
- D, immunoglobulin G: is an antibody, not a clotting substrate.

Final Answer: fibrinogen $\Rightarrow$ $\boxed{\text{B}}$

Answer: (B) Go Back to Q5

Q6.

Solution

Concept – ABO grouping by antigens and antibodies: The ABO group is named for the antigens on the red cells; the plasma carries antibodies against the antigens the person lacks.

Step 1 – read the antigen status: The red cells carry neither A nor B antigen.

Step 2 – read the antibody status: The plasma contains both anti-A and anti-B, consistent with lacking both antigens.

Step 3 – name the group: No A or B antigen means group O.

Why the other options are wrong:

- B, group AB: carries both antigens and neither antibody.
- C, group A: carries the A antigen and anti-B only.
- D, group B: carries the B antigen and anti-A only.

Final Answer: group O $\Rightarrow$ $\boxed{\text{A}}$

Answer: (A) Go Back to Q6

Q7.

Solution

Concept – Fourier series of an odd square wave: Symmetry of a periodic signal decides which harmonics appear.

Step 1 – use the odd-function property: An odd function ($x(-t) = -x(t)$) has a Fourier series made only of sine terms, and its DC (average) value is zero.

Step 2 – use the half-wave symmetry of a square wave: A symmetric square wave also has half-wave symmetry ($x(t \pm T/2) = -x(t)$), which removes all even harmonics.

Step 3 – combine the two results: Only odd-numbered sine harmonics survive: $x(t) = \frac{4A}{\pi}\left(\sin\omega_0 t + \frac{1}{3}\sin 3\omega_0 t + \frac{1}{5}\sin 5\omega_0 t + \dots\right)$.

Why the other options are wrong:

- A: even harmonics are absent, not exclusively present.
- B: the DC term is zero for a zero-mean wave.
- C: cosine terms belong to even functions, not this odd one.

Final Answer: only odd harmonics (sine terms), no DC $\Rightarrow$ D

Answer: (D) Go Back to Q7

Q8.

Solution

Concept – fundamental frequency from period: $f_0 = \frac{1}{T}$.

Step 1 – convert the period to seconds: $T = 20$ ms $= 20 \times 10^{-3}$ s $= 0.02$ s.

Step 2 – take the reciprocal: $f_0 = \frac{1}{0.02}$

Step 3 – evaluate: $f_0 = 50$ Hz

Why the other options are wrong:

- B, 20 Hz: uses the number 20 directly without converting ms.
- C, 100 Hz, and D, 500 Hz: do not follow from $1/T$.

Final Answer: $f_0 = 50$ Hz $\Rightarrow$ A

Answer: (A) Go Back to Q8

Q9.

Solution

Concept – Fourier series of an even signal: The parity of a periodic signal fixes whether cosines or sines appear.

Step 1 – apply the even-function rule: For $x(-t) = x(t)$, all sine coefficients b_n vanish because $\sin$ is odd.

Step 2 – keep the surviving terms: Only cosine terms $a_n \cos(n\omega_0 t)$ remain, plus a possible DC term a_0 if the average is nonzero.

Why the other options are wrong:

- A: sine terms are exactly the ones that vanish.
- C: parity restricts sine/cosine content, not the odd/even harmonic number.
- D: an even signal can have a nonzero average, hence a DC term.

Final Answer: only cosine terms (plus a possible DC term) $\Rightarrow$ $\boxed{\text{B}}$

Answer: (B) Go Back to Q9

Q10.

Solution

Concept – input–output relation of an LTI system: An LTI system is fully described by its impulse response $h(t)$.

Step 1 – state the defining operation: The output is the convolution of the input with the impulse response: $y(t) = x(t) * h(t) = \int_{-\infty}^{\infty} x(\tau)\, h(t-\tau)\, d\tau$.

Step 2 – interpret: Each input value is spread out by $h(t)$ and the contributions are summed, which is convolution.

Why the other options are wrong:

- A: multiplication in time would correspond to modulation, not filtering.
- B: simple addition is not how a system transforms its input.
- C: differentiation is only one very special impulse response, not the general rule.

Final Answer: $y(t) = x(t) * h(t)$ (convolution) $\Rightarrow$ $\boxed{\text{D}}$

Answer: (D) Go Back to Q10

Q11.

Solution

Concept – memory of a system: A system has memory if its present output can depend on past (or future) input values.

Step 1 – read the given condition: The output depends only on the present input value.

Step 2 – classify: With no dependence on past or future inputs, the system is memoryless (static).

Why the other options are wrong:

- A, dynamic: means it does have memory, the opposite of the given condition.
- C, unstable: is about bounded output, a separate property.
- D, time-varying: is about how the response changes with time, also separate.

Final Answer: memoryless (static) $\Rightarrow$ B

Answer: (B) Go Back to Q11

Q12.

Solution

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

Step 1 – list the data: $R_1 = 6\ \text{k}\Omega$, $R_2 = 3\ \text{k}\Omega$.

Step 2 – form the product: $R_1 R_2 = 6 \times 3 = 18\ (\text{k}\Omega)^2$

Step 3 – form the sum: $R_1 + R_2 = 6 + 3 = 9\ \text{k}\Omega$

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

$R_{eq} = 2\ \text{k}\Omega$

Why the other options are wrong:

- A, $9\ \text{k}\Omega$: is the series sum, not the parallel value.
- B, $4.5\ \text{k}\Omega$: would be the parallel of two equal $9\ \text{k}\Omega$ resistors.
- D, $18\ \text{k}\Omega$: is only the numerator product.

Final Answer: $R_{eq} = 2\ \text{k}\Omega \Rightarrow$ C

Answer: (C) Go Back to Q12

Q13.

Solution

Concept – symmetry of exponential Fourier coefficients: For a real signal the positive- and negative-index coefficients are related.

Step 1 – write the coefficient definition: $c_n = \dfrac{1}{T}\displaystyle\int_T x(t)\, e^{-jn\omega_0 t}\, dt$.

Step 2 – replace n by $-n$ and take the complex conjugate: Because $x(t)$ is real, $c_{-n} = \dfrac{1}{T}\int_T x(t)\, e^{+jn\omega_0 t}\, dt = c_n^*$.

Step 3 – state the result: The coefficients obey conjugate (Hermitian) symmetry, $c_{-n} = c_n^*$, so their magnitudes are even and their phases are odd.

Why the other options are wrong:

- A and B: hold only for purely even or purely odd real signals, not in general.
- C: negative-index coefficients are generally nonzero for a real signal.

Final Answer: $c_{-n} = c_n^*$ (conjugate symmetry) $\Rightarrow$ D

Answer: (D) Go Back to Q13

Q14.

Solution

Concept – amplifier classes by conduction angle: The class is set by the fraction of the input cycle for which the output device conducts.

Step 1 – match the conduction angle: Conduction for the full $360°$ of the cycle corresponds to Class A.

Step 2 – note the trade-off: Class A gives the most faithful (low-distortion) output but has poor efficiency (theoretical maximum 25% for a resistive load) because the device carries current even with no signal.

Why the other options are wrong:

- B, Class B: each device conducts for only $180°$.
- C, Class C: conduction is less than $180°$.
- D, Class D: is a switching (ON/OFF) amplifier, not a full-cycle linear one.

Final Answer: Class A $\Rightarrow$ A

Answer: (A) Go Back to Q14

Q15.

Solution

Concept – efficiency of an ideal Class B push-pull stage: Efficiency is the ratio of AC load power to DC supply power at full drive.

Step 1 – recall the standard result: For an ideal Class B push-pull amplifier at maximum sinusoidal output, the theoretical efficiency is $\eta_{max} = \frac{\pi}{4}$.

Step 2 – evaluate as a percentage: $\eta_{max} = \frac{\pi}{4} = 0.785 = 78.5\%$.

Why the other options are wrong:

- A, 25%: is the ideal maximum for Class A.
- B, 50%: is a common misremembering; the correct figure is higher.
- C, 100%: is unattainable for a linear stage (only idealised switching stages approach it).

Final Answer: $\eta_{max} \approx 78.5\% \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q15

Q16.

Solution

Concept – distortion in Class B push-pull: When the drive passes through zero, both transistors can be off for a short interval.

Step 1 – read the waveform: The output is flattened around each zero crossing, exactly where one transistor hands over to the other.

Step 2 – name the effect: This dead-band flattening at the handover is crossover distortion, caused by the base-emitter turn-on threshold (≈ 0.6–0.7 V) of the transistors.

Step 3 – note the fix: A small forward bias (Class AB) keeps both devices slightly conducting near zero and removes the notch.

Why the other options are wrong:

- A: harmonic distortion is a description of the result, not the named zero-crossing effect.
- B: saturation distortion clips the peaks, not the zero crossing.
- D: intermodulation needs two or more input tones.

Final Answer: crossover distortion $\Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q16

Q17.

Solution

Concept – Class C applications: A conduction angle well below 180° produces a distorted current pulse rich in harmonics.

Step 1 – note the distortion: Because it conducts for only a small part of the cycle, a Class C stage is far too non-linear for audio.

Step 2 – restore the sine wave with a tuned load: A parallel LC tank at the output rings sinusoidally, selecting the desired carrier frequency from the pulse.

Step 3 – identify the use: This makes Class C ideal as an efficient tuned radio-frequency power amplifier (RF transmitters, oscillators).

Why the other options are wrong:

- A: high-fidelity audio needs low distortion (Class A/AB), not Class C.
- B: it cannot amplify DC, having no full-cycle conduction.
- D: biopotential amplifiers must be highly linear.

Final Answer: tuned radio-frequency power amplifier $\Rightarrow$ C

Answer: (C) Go Back to Q17

Q18.

Solution

Concept – exclusive-OR truth table: An XOR gate outputs 1 only when its two inputs differ.

Step 1 – write the XOR relation: $Y = A \oplus B = A\bar{B} + \bar{A}B$.

Step 2 – substitute $A = 1$, $B = 1$: $Y = (1)(\bar{1}) + (\bar{1})(1) = (1)(0) + (0)(1)$

Step 3 – evaluate: $Y = 0 + 0 = 0$

Step 4 – interpret: Because the inputs are equal, the XOR output is 0.

Why the other options are wrong:

- A, 1: would require the inputs to differ.
- B, high impedance: an XOR gate always drives a defined logic level.
- C, undefined: the output is well defined for defined inputs.

Final Answer: $Y = 0 \Rightarrow$ D

Answer: (D) Go Back to Q18

Q19.

Solution

Concept – Class D switching operation: A Class D amplifier does not amplify the signal linearly; it encodes it and switches.

Step 1 – describe the operation: The audio (or bio-) signal is converted to a pulse-width-modulated stream, and the output transistors are switched fully ON or fully OFF at high frequency.

Step 2 – explain the efficiency: A switch in the ON state has near-zero voltage across it, and in the OFF state near-zero current through it, so the transistor dissipates very little power; ideal efficiency approaches 100%.

Step 3 – recover the signal: A low-pass output filter averages the PWM waveform back into the amplified analog signal.

Why the other options are wrong:

- A: linear active operation is what Classes A/AB do, with much higher losses.
- B and C: staying only at cutoff or only in saturation cannot reproduce a signal.

Final Answer: operated as ON/OFF switches with PWM $\Rightarrow$ $\boxed{\text{D}}$

Answer: (D) Go Back to Q19

Q20.

Solution

Concept – surface biopotential electrode: Surface recordings need an electrode that does not build up a large, drifting interface potential.

Step 1 – state the requirement: A good surface electrode should be non-polarisable, letting charge cross the interface freely so its half-cell potential stays low and stable.

Step 2 – identify the material: The silver–silver chloride (Ag/AgCl) electrode is essentially non-polarisable and has a stable half-cell potential, so it is the standard for ECG/EEG/EMG.

Why the other options are wrong:

- B, pure platinum: is strongly polarisable and behaves capacitively.

- C, stainless steel: is used for needles but has a less stable interface potential.
- D, pure gold: is inert but polarisable and not the routine surface choice.

Final Answer: silver–silver chloride (Ag/AgCl) $\Rightarrow$ A

Answer: (A) Go Back to Q20

Q21.

Solution

Concept – electrode–electrolyte equivalent circuit: When a metal electrode touches an electrolyte, charge separation forms a double layer and there is a finite rate of charge transfer.

Step 1 – identify each element: E_{hc} is the half-cell potential (the battery), R_s is the spreading/electrolyte series resistance.

Step 2 – interpret the parallel $R_{ct} \parallel C_{dl}$: C_{dl} is the double-layer capacitance formed by charge lined up on either side of the interface; R_{ct} (the Faradaic / charge-transfer resistance) is the leakage path for charge that actually crosses the interface.

Step 3 – match to the option: Hence the parallel pair represents the double-layer capacitance together with the charge-transfer resistance at the metal–electrolyte interface.

Why the other options are wrong:

- A: lead inductance is negligible at biopotential frequencies.
- B: the amplifier input impedance is a separate, external element.
- C: sweat glands contribute to the skin model, but the $R_{ct} \parallel C_{dl}$ pair specifically models the electrode interface.

Final Answer: double-layer capacitance with charge-transfer resistance $\Rightarrow$ D

Answer: (D) Go Back to Q21

Q22.

Solution

Concept – differential electrode offset: Two electrodes in a lead each contribute a half-cell potential; the amplifier sees their difference.

Step 1 – list the two half-cell potentials: $E_1 = +0.223$ V, $E_2 = +0.213$ V.

Step 2 – take the difference: $\Delta E = E_1 - E_2 = 0.223 - 0.213$

Step 3 – evaluate: $\Delta E = 0.010$ V $= 10$ mV

Step 4 – interpret: This 10 mV DC offset is much larger than the ECG itself (~ 1 mV), which is why AC coupling or offset rejection is needed.

Why the other options are wrong:

- A, 0.436 V: is the sum, not the difference.
- B and D: are the individual half-cell potentials, not the differential offset.

Final Answer: $\Delta E = 10$ mV $\Rightarrow$ C

Answer: (C) Go Back to Q22

Q23.

Solution

Concept – polarisable electrode behaviour: A perfectly polarisable electrode allows no net charge to cross the interface.

Step 1 – reason about charge flow: If no charge crosses, current can only flow by charging and discharging the double layer.

Step 2 – identify the electrical element: An element that passes current only by charge accumulation is a capacitor; the charge-transfer resistance $R_{ct} \to \infty$.

Step 3 – conclude: So a perfectly polarisable electrode (e.g. smooth platinum) behaves at the interface essentially as a capacitor.

Why the other options are wrong:

- B: a pure resistor describes the opposite (non-polarisable, freely conducting) case.
- C: it is not a source of EMF by itself in this idealisation.
- D: there is no inductive behaviour at the interface.

Final Answer: capacitor $\Rightarrow$ A

Answer: (A) Go Back to Q23

Q24.

Solution

Concept – lowering skin–electrode impedance: Motion artefact and high contact impedance are dominated by the dry outer skin layer.

Step 1 – locate the high-impedance layer: The stratum corneum (dead outer epidermis) has the highest impedance and drifts with movement.

Step 2 – state the standard preparation: Lightly abrading this layer and applying a conductive electrolyte gel provides a stable, low-impedance ionic path.

Step 3 – conclude: This preparation reduces both the contact impedance and the motion artefact.

Why the other options are wrong:

- A: shrinking the contact area raises the impedance.
- B and C: recording through untouched, dry skin gives the worst impedance and most artefact.

Final Answer: abrade the stratum corneum and apply electrolyte gel $\Rightarrow$ $\boxed{\text{D}}$

Answer: (D) Go Back to Q24

Q25.

Solution

Concept – source loading (voltage divider): A source with internal resistance drives a finite input resistance, and the two form a divider.

Step 1 – list the data: Source EMF $V_s = 2.0$ mV, source resistance $R_s = 50$ kΩ, amplifier input resistance $R_{in} = 950$ kΩ.

Step 2 – write the divider relation: $V_{meas} = V_s \cdot \dfrac{R_{in}}{R_s + R_{in}}$

Step 3 – form the denominator: $R_s + R_{in} = 50 + 950 = 1000$ kΩ

Step 4 – substitute: $V_{meas} = 2.0 \times \dfrac{950}{1000}$

Step 5 – evaluate: $V_{meas} = 2.0 \times 0.95 = 1.9$ mV

Step 6 – interpret: The 0.1 mV (5%) loss shows why biopotential amplifiers need $R_{in} \gg R_s$ (typically ≥ 10 MΩ).

Why the other options are wrong:

- A, 2.0 mV: ignores loading (would need infinite R_{in}).
- C, 0.1 mV: is the voltage lost across R_s, not the measured value.

- D, 1.0 mV: would correspond to equal resistances.

Final Answer: $V_{meas} = 1.9$ mV $\Rightarrow$ B

Answer: (B) Go Back to Q25

Q26.

Solution

Concept – FIR versus IIR structure: Digital filters are classed by whether their impulse response is finite and whether feedback is used.

Step 1 – read the two defining clues: The impulse response has finitely many nonzero samples, and there is no feedback of past outputs.

Step 2 – match to the class: A non-recursive filter with a finite impulse response is, by definition, an FIR filter; its output is $y[n] = \sum_{k=0}^{M} b_k\, x[n-k]$.

Why the other options are wrong:

- A: an IIR filter uses feedback and has an infinitely long impulse response.
- C: it is a discrete-time digital filter, not an analog one.
- D: an all-pass recursive filter is a type of IIR filter.

Final Answer: finite impulse response (FIR) filter $\Rightarrow$ B

Answer: (B) Go Back to Q26

Q27.

Solution

Concept – linear phase of FIR filters: Phase linearity determines whether different frequency components are delayed by the same time.

Step 1 – state the FIR property: An FIR filter with symmetric (or antisymmetric) coefficients has exactly linear phase, i.e. a constant group delay.

Step 2 – explain the benefit: Constant group delay means the filter delays all frequencies equally, so the waveform shape of a pulse (such as the QRS complex of an ECG) is preserved without phase distortion.

Step 3 – contrast with IIR: A stable IIR filter generally cannot have exactly linear phase.

Why the other options are wrong:

- B: FIR filters usually need more coefficients than an IIR filter for the same sharpness.
- C and D: an FIR filter has no poles away from the origin, so it is always stable, not unstable.

Final Answer: exactly linear phase (constant group delay) $\Rightarrow$ A

Answer: (A) Go Back to Q27

Q28.

Solution

Concept – frequency response of a first difference: $y[n] = x[n] - x[n-1]$ is the discrete analogue of differentiation.

Step 1 – write the transfer function: $H(z) = 1 - z^{-1}$.

Step 2 – evaluate on the unit circle ($z = e^{j\omega}$): $H(e^{j\omega}) = 1 - e^{-j\omega}$, so $|H(e^{j\omega})| = 2\,|\sin(\omega/2)|$.

Step 3 – inspect the magnitude: At $\omega = 0$ (DC), $|H| = 0$; at $\omega = \pi$ (highest frequency), $|H| = 2$ (maximum). The gain rises with frequency.

Step 4 – classify: Blocking DC and passing high frequencies is high-pass (differencing) behaviour.

Why the other options are wrong:

- A: a low-pass filter would pass DC and attenuate high frequencies, the opposite here.
- B: an all-pass filter has constant magnitude.
- C: there is no resonant peak at an intermediate frequency.

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

Answer: (D) Go Back to Q28

Q29.

Solution

Concept – stability of a causal discrete-time system: Stability of an IIR filter is read from the pole locations on the z-plane relative to the unit circle.

Step 1 – state the region of convergence condition: For a causal system the region of convergence is the exterior of the outermost pole; stability requires the

unit circle to lie in the region of convergence.

Step 2 – combine the two: Both conditions hold together only if every pole lies strictly inside the unit circle, $|z_{pole}| < 1$.

Step 3 – read the map: The crosses (poles) in the sketch sit inside the unit circle, so the filter is causal and stable.

Why the other options are wrong:

- B: poles outside the unit circle make a causal system unstable.
- C: poles on the unit circle give a marginally stable (non-decaying) response.
- D: poles need not be at the origin (that would be a pure FIR delay).

Final Answer: all poles inside the unit circle ($|z| < 1$) $\Rightarrow$ A

Answer: (A) Go Back to Q29

Q30.

Solution

Concept – normalised versus analog frequency: A normalised frequency given as a fraction of the sampling rate is converted by multiplying by f_s.

Step 1 – list the data: $f_s = 8$ kHz $= 8000$ Hz, normalised cut-off $= 0.25$.

Step 2 – multiply: $f_c = 0.25 \times f_s = 0.25 \times 8000$

Step 3 – evaluate: $f_c = 2000$ Hz

Step 4 – sanity check: This is half the Nyquist frequency ($f_s/2 = 4000$ Hz), consistent with a normalised value of 0.25.

Why the other options are wrong:

- A, 4000 Hz: is the full Nyquist frequency (normalised 0.5).
- C, 1000 Hz: corresponds to normalised 0.125.
- D, 8000 Hz: is the sampling frequency itself.

Final Answer: $f_c = 2000$ Hz $\Rightarrow$ B

Answer: (B) Go Back to Q30

Q31.

Solution

Concept – origin of the Doppler shift in blood-flow imaging: The Doppler shift arises from motion of whatever scatters the ultrasound.

Step 1 – identify the scatterers in blood: Within a vessel the dominant moving scatterers are the red blood cells.

Step 2 – relate motion to frequency shift: Sound scattered from cells moving toward the probe returns at a higher frequency, and from cells moving away at a lower frequency; the shift encodes their velocity.

Why the other options are wrong:

- A: bone is essentially stationary and gives no flow-related shift.
- C: the crystal is fixed and does not move with the flow.
- D: stationary walls produce the low-frequency clutter that wall filters remove, not the flow signal.

Final Answer: red blood cells (moving scatterers) $\Rightarrow$ $\boxed{\text{B}}$

Answer: (B) Go Back to Q31

Q32.

Solution

Concept – Doppler shift formula: $f_d = \dfrac{2 f_0 v \cos\theta}{c}$, the factor 2 arising from the round trip.

Step 1 – list the data: $f_0 = 5$ MHz $= 5 \times 10^6$ Hz, $v = 0.5$ m/s, $\cos\theta = 1$, $c = 1540$ m/s.

Step 2 – form the numerator: $2 f_0 v \cos\theta = 2 \times 5 \times 10^6 \times 0.5 \times 1$

$= 5 \times 10^6$

Step 3 – divide by c: $f_d = \dfrac{5 \times 10^6}{1540}$

Step 4 – evaluate: $f_d \approx 3247$ Hz ≈ 3.2 kHz

Step 5 – interpret: A shift of a few kilohertz falls in the audible range, which is why Doppler signals can be played as sound.

Why the other options are wrong:

- A, 1.6 kHz: omits the round-trip factor of 2.
- B, 6.5 kHz: doubles the correct value.

- D, 0.65 kHz: is off by an order of magnitude.

Final Answer: $f_d \approx 3.2$ kHz $\Rightarrow$ C

Answer: (C) Go Back to Q32

Q33.

Solution

Concept – CW versus PW Doppler: Continuous-wave Doppler transmits and receives continuously with no timing gate.

Step 1 – note what CW lacks: Because it emits sound continuously, CW Doppler cannot time the echo return, so it cannot tell the depth from which a signal originates.

Step 2 – state the consequence: It measures the combined flow along the whole beam and gives no range (depth) resolution, so it cannot isolate one vessel at a chosen depth.

Step 3 – note the compensating strength: In return, CW Doppler has no aliasing limit and can measure very high velocities.

Why the other options are wrong:

- A: CW actually excels at high velocities (no Nyquist limit).
- B: needing two elements is a hardware detail, not the principal limitation.
- D: CW Doppler can still detect flow direction with quadrature demodulation.

Final Answer: no depth (range) resolution $\Rightarrow$ C

Answer: (C) Go Back to Q33

Q34.

Solution

Concept – angle dependence of the Doppler shift: $f_d \propto \cos\theta$, so the shift is largest when $\cos\theta$ is largest.

Step 1 – maximise $\cos\theta$: $\cos\theta$ is greatest $(= 1)$ when $\theta = 0°$, i.e. the beam is parallel to the flow.

Step 2 – note the worst case: At $\theta = 90°$, $\cos\theta = 0$ and the measured shift vanishes, so a near-perpendicular beam gives an unreliable reading.

Step 3 – practical rule: Operators keep the insonation angle small (in practice

below about $60°$) to maximise and stabilise the shift.

Why the other options are wrong:

- B: $90°$ gives zero shift.
- C: $180°$ gives the same magnitude as $0°$ but is not the only useful value, and only reverses sign.
- D: the shift clearly depends on angle through $\cos\theta$.

Final Answer: keep θ close to $0° \Rightarrow$ A

Answer: (A) Go Back to Q34

Q35.

Solution

Concept – Nyquist limit in pulsed-wave Doppler: The pulse-repetition frequency (PRF) is the effective sampling rate of the Doppler signal.

Step 1 – apply the sampling theorem: The largest frequency that can be sampled without aliasing is half the sampling rate.

Step 2 – substitute the PRF: $f_{d,max} = \dfrac{\text{PRF}}{2} = \dfrac{8 \text{ kHz}}{2}$

Step 3 – evaluate: $f_{d,max} = 4$ kHz

Step 4 – interpret: A Doppler shift above 4 kHz would alias (wrap around), the familiar aliasing artefact seen in PW Doppler of fast jets.

Why the other options are wrong:

- B, 8 kHz: is the PRF itself, not the Nyquist limit.
- C, 16 kHz: is twice the PRF.
- D, 2 kHz: would correspond to a PRF of 4 kHz.

Final Answer: $f_{d,max} = 4$ kHz $\Rightarrow$ A

Answer: (A) Go Back to Q35

Q36.

Solution

Concept – electrical analogue of the Windkessel model: The Windkessel model maps haemodynamic quantities onto circuit elements: pressure $\leftrightarrow$ voltage, flow $\leftrightarrow$ current.

Step 1 – map the elastic reservoir: The large arteries store blood elastically during systole; storage of a "through" variable against a "cross" variable is capacitive, so compliance maps to a capacitor.

Step 2 – map the peripheral bed: The peripheral (small-vessel) resistance to outflow maps to a resistor in parallel with that capacitor.

Step 3 – assemble the two-element model: The classic two-element Windkessel is therefore a capacitor (compliance) in parallel with a resistor (peripheral resistance).

Why the other options are wrong:

- A: an inductor represents blood inertance, which is added only in more elaborate (three- and four-element) models.
- B: a constant-voltage source would fix pressure, not model storage.
- C: a diode has no role in the linear two-element model.

Final Answer: capacitor in parallel with a resistor $\Rightarrow$ D

Answer: (D) Go Back to Q36

Q37.

Solution

Concept – systemic vascular resistance: $R = \dfrac{\Delta P}{Q}$, the pressure drop across the circulation divided by the flow through it.

Step 1 – form the pressure drop: $\Delta P = P_{arterial} - P_{atrial} = 100 - 0 = 100$ mmHg.

Step 2 – list the flow: $Q = 5$ L/min.

Step 3 – divide: $R = \dfrac{100}{5}$

Step 4 – evaluate: $R = 20$ mmHg·min/L

Why the other options are wrong:

- B, 500: multiplies instead of dividing.
- C, 5: is the cardiac output, not the resistance.

- D, 0.05: inverts the ratio.

Final Answer: $R = 20$ mmHg·min/L $\Rightarrow$ A

Answer: (A) Go Back to Q37

Q38.

Solution

Concept – arterial compliance: $C = \dfrac{\Delta V}{\Delta P}$, the volume stored per unit rise in pressure.

Step 1 – list the data: $\Delta V = 2$ mL, $\Delta P = 40$ mmHg.

Step 2 – substitute: $C = \dfrac{2}{40}$

Step 3 – evaluate: $C = 0.05$ mL/mmHg

Step 4 – interpret: A small compliance means the segment is stiff, so a given volume change produces a large pressure change.

Why the other options are wrong:

- A, 20 mL/mmHg: inverts the ratio ($\Delta P/\Delta V$).
- B, 80: multiplies instead of dividing.
- D, 0.5: is ten times too large.

Final Answer: $C = 0.05$ mL/mmHg $\Rightarrow$ C

Answer: (C) Go Back to Q38

Q39.

Solution

Concept – diastolic pressure decay of the Windkessel: During diastole the aortic valve is shut, so the charged compliance discharges through the peripheral resistance.

Step 1 – write the balance with no inflow: With $Q_{in} = 0$, the flow out of the capacitor equals the flow through the resistor: $C\dfrac{dP}{dt} = -\dfrac{P}{R}$.

Step 2 – solve the first-order equation: $\dfrac{dP}{P} = -\dfrac{1}{RC}\,dt$, which integrates to $P(t) = P_0\, e^{-t/(RC)}$.

Step 3 – identify the decay: The pressure falls exponentially with time constant $\tau = RC$.

Why the other options are wrong:

- A: a linear fall is not the solution of an RC discharge.
- B: the pressure does not drop instantly; the reservoir sustains it.
- D: a rising ramp contradicts an emptying reservoir.

Final Answer: exponential decay with $\tau = RC \Rightarrow$ C

Answer: (C) Go Back to Q39

Q40.

Solution

Concept – Poiseuille's fourth-power law: $Q \propto r^4$ at constant pressure, viscosity and length.

Step 1 – write the ratio: $\dfrac{Q_2}{Q_1} = \left(\dfrac{r_2}{r_1}\right)^4$.

Step 2 – substitute $r_2 = \frac{1}{2}r_1$**:** $\dfrac{Q_2}{Q_1} = \left(\dfrac{1}{2}\right)^4$

Step 3 – evaluate the power: $\left(\dfrac{1}{2}\right)^4 = \dfrac{1}{16}$

Step 4 – interpret: Halving the radius cuts the flow to one-sixteenth, showing how sensitively flow depends on vessel calibre.

Why the other options are wrong:

- A, $1/2$: would apply only if $Q \propto r$.
- C, $1/4$: would apply if $Q \propto r^2$.
- D, $1/8$: would apply if $Q \propto r^3$.

Final Answer: one-sixteenth of the flow $\Rightarrow$ B

Answer: (B) Go Back to Q40

Q41.

Solution

Concept – Laplace's law for a thin-walled cylinder: Wall tension per unit length $T = P\,r$ for a cylindrical vessel.

Step 1 – list the data in SI units: $P = 13000$ Pa, $r = 0.01$ m.

Step 2 – substitute: $T = 13000 \times 0.01$

Step 3 – evaluate: $T = 130$ N/m

Step 4 – interpret: This is why dilated vessels (larger r) must withstand a higher wall tension at the same pressure, relevant to aneurysm rupture.

Why the other options are wrong:

- A, 1.3 N/m: is off by a factor of 100.
- B, 13 N/m: is off by a factor of 10.
- D, 1300 N/m: is ten times too large.

Final Answer: $T = 130$ N/m $\Rightarrow$ C

Answer: (C) Go Back to Q41

Q42.

Solution

Concept – modulation in biotelemetry: The biosignal is impressed on an RF carrier before transmission; the scheme chosen affects noise immunity.

Step 1 – read the described action: The biosignal varies the instantaneous *frequency* of the carrier.

Step 2 – name it: Varying carrier frequency with the message is frequency modulation (FM).

Step 3 – note the advantage: FM keeps the information in the frequency, not the amplitude, so it is largely immune to amplitude noise and fading, which is valuable for weak biotelemetry links.

Why the other options are wrong:

- A: amplitude modulation puts the signal in the amplitude, which is easily corrupted by noise.
- B: PCM is a digital coding scheme, not what is described here.
- D: baseband transmission uses no carrier and cannot be radiated efficiently.

Final Answer: frequency modulation (FM) $\Rightarrow$ C

Answer: (C) Go Back to Q42

Q43.

Solution

Concept – biotelemetry transmitter signal chain: The signal must be sensed, made large enough, impressed on a carrier, and then radiated.

Step 1 – start at the body: A transducer (electrode or sensor) picks up the biological signal.

Step 2 – condition it: The weak signal is boosted by an amplifier.

Step 3 – impress it on a carrier: A modulator places the amplified signal onto an RF carrier.

Step 4 – radiate it: An RF transmitter drives the antenna to send the signal out.

Step 5 – state the order: transducer $\rightarrow$ amplifier $\rightarrow$ modulator $\rightarrow$ RF transmitter (antenna).

Why the other options are wrong:

- A, B, C: all place the antenna or modulator before the transducer/amplifier, which reverses the physical signal flow.

Final Answer: transducer $\rightarrow$ amplifier $\rightarrow$ modulator $\rightarrow$ RF transmitter $\Rightarrow$ D

Answer: (D) Go Back to Q43

Q44.

Solution

Concept – wavelength of a carrier: $\lambda = \dfrac{c}{f}$.

Step 1 – list the data: $c = 3 \times 10^8$ m/s, $f = 400$ MHz $= 400 \times 10^6$ Hz $= 4 \times 10^8$ Hz.

Step 2 – substitute: $\lambda = \dfrac{3 \times 10^8}{4 \times 10^8}$

Step 3 – cancel the powers of ten: $\lambda = \dfrac{3}{4}$

Step 4 – evaluate: $\lambda = 0.75$ m

Step 5 – interpret: A wavelength of 0.75 m sets the scale of the (often miniaturised) implant antenna.

Why the other options are wrong:

- A, 1.33 m: inverts the ratio.
- C, 7.5 m, and D, 0.075 m: are off by factors of ten.

Final Answer: $\lambda = 0.75$ m $\Rightarrow$ B

Answer: (B) Go Back to Q44

Q45.

Solution

Concept – constraints on an implanted telemetry device: An in-body device cannot be serviced easily and must coexist safely with tissue.

Step 1 – power constraint: The device runs from a tiny implanted battery or inductive coupling, so it must draw extremely low power to last for years.

Step 2 – packaging constraint: It must be encased in a biocompatible, hermetically sealed package so that body fluids do not corrode the electronics and the material does not harm tissue.

Step 3 – combine: The distinguishing constraint of an implant, versus a wearable, is the pairing of ultra-low power with a biocompatible, hermetic package.

Why the other options are wrong:

- B: a mains supply cannot be placed inside the body.
- C: a cooling fan is impossible and unnecessary for a micro-power implant.
- D: a permanent wired link would breach the skin and defeat the purpose of telemetry.

Final Answer: ultra-low power with biocompatible, hermetic packaging $\Rightarrow$ A

Answer: (A) Go Back to Q45

Q46.

Solution

Concept – closed-loop gain with negative feedback: For a single loop, $\frac{C}{R} = \frac{G}{1+GH}$.

Step 1 – list the data: $G = 9$, $H = 1$ (unity feedback).

Step 2 – form the loop gain: $GH = 9 \times 1 = 9$.

Step 3 – form the denominator: $1 + GH = 1 + 9 = 10$.

Step 4 – divide: $\frac{C}{R} = \frac{9}{10}$

Step 5 – evaluate: $\frac{C}{R} = 0.9$

Step 6 – interpret: The closed-loop gain (0.9) is well below the open-loop gain (9); negative feedback trades gain for stability and accuracy, desirable in a drug-infusion controller.

Why the other options are wrong:

- A, 9: is the forward (open-loop) gain, ignoring feedback.
- C, 0.1: is $1/(1+G)$ misapplied.
- D, 10: is the denominator, not the ratio.

Final Answer: $\frac{C}{R} = 0.9 \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q46

Answer Key

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