GATE Biomedical Engineering

Sample Paper – 6

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 hormone that lowers blood glucose by promoting the uptake of glucose into cells, secreted by the beta cells of the islets of Langerhans in the pancreas, is: **[1 mark]**

(A) insulin

(B) glucagon

(C) thyroxine

(D) cortisol

Q2. Which endocrine gland, located in the front of the neck, secretes the hormones thyroxine (T_4) and triiodothyronine (T_3) that set the body's basal metabolic rate? **[1 mark]**

(A) adrenal gland

(B) pituitary gland

(C) thyroid gland

(D) pineal gland

Q3. The proteolytic enzyme secreted by the gastric glands of the stomach, which begins the digestion of proteins only in a strongly acidic environment, is: **[1 mark]**

(A) salivary amylase

(B) pancreatic lipase

(C) trypsin

(D) pepsin

Q4. The pH scale below marks the acidity of gastric juice in the stomach lumen during active digestion. The value of gastric pH is nearest to: **[1 mark]**

(A) about 2

(B) about 7

(C) about 9

(D) about 12

Q5. The "fight or flight" hormone secreted by the medulla of the adrenal gland in response to acute stress, which raises heart rate and dilates the airways, is: **[1 mark]**

(A) adrenaline (epinephrine)

(B) insulin

(C) melatonin

(D) oxytocin

Q6. The largest gland in the human body, which secretes bile that emulsifies dietary fat and also stores glucose as glycogen, is the: **[1 mark]**

(A) pancreas

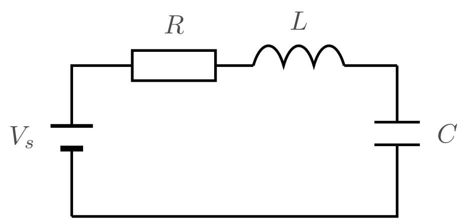
(B) spleen

(C) liver

(D) gall bladder

Electric Circuits, Signals and Systems

Q7. For the series RLC circuit shown, $L = 100$ mH and $C = 10$ μF. The resonant frequency $f_0 = \dfrac{1}{2\pi\sqrt{LC}}$ is nearest to: **[1 mark]**



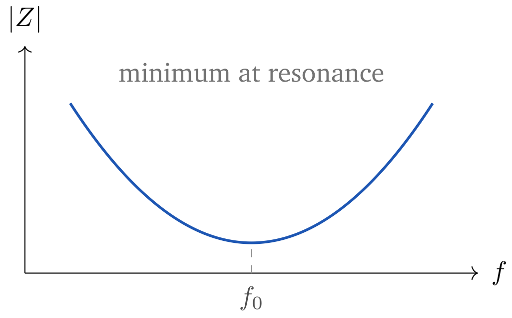
(A) 1000 Hz

(B) 50 Hz

(C) 159 Hz

(D) 16 Hz

Q8. The magnitude of the impedance of a series RLC circuit is sketched against frequency below. At the resonant frequency f_0, the inductive and capacitive reactances cancel, so the impedance presented to the source is: **[1 mark]**



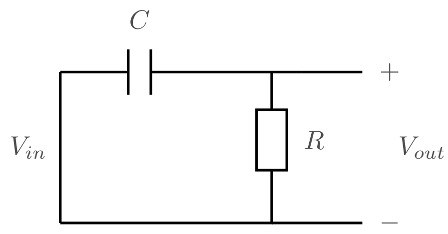
(A) minimum and equal to R

(B) maximum and equal to R

(C) zero

(D) infinite

Q9. In the first-order RC network shown, the output is taken across the resistor R while the capacitor C is in the series path. This configuration behaves as a: **[1 mark]**



(A) low-pass filter

(B) high-pass filter

(C) band-pass filter

(D) notch (band-reject) filter

Q10. A first-order RL low-pass filter has $R = 2$ kΩ and $L = 100$ mH. Its -3 dB cut-off frequency $f_c = \dfrac{R}{2\pi L}$ is nearest to: **[1 mark]**

(A) 3.18 kHz

(B) 318 Hz

(C) 31.8 kHz

(D) 100 Hz

Q11. For a series RLC resonant circuit, the quality factor Q is related to the resonant frequency f_0 and the -3 dB bandwidth BW by: **[1 mark]**

(A) $Q = \frac{\text{BW}}{f_0}$

(B) $Q = f_0 \cdot \text{BW}$

(C) $Q = \frac{f_0}{\text{BW}}$

(D) $Q = \frac{1}{f_0 \cdot \text{BW}}$

Q12. The reactance of an ideal capacitor is $X_C = \frac{1}{2\pi f C}$. As the signal frequency f increases, the capacitive reactance: **[1 mark]**

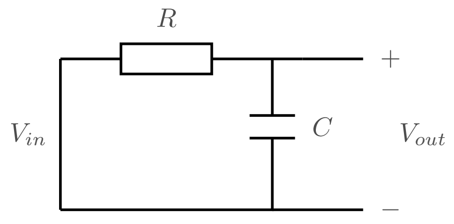
(A) increases in direct proportion to f

(B) decreases

(C) stays constant

(D) becomes infinite

Q13. The first-order RC low-pass (integrator) network shown has $R = 1$ kΩ and $C = 0.1$ μF. The time constant $\tau = RC$ of the network is: **[1 mark]**



(A) 0.1 ms

(B) 1 ms

(C) 10 ms

(D) 1 μs

Analog and Digital Electronics

Q14. A digital-to-analog converter (DAC) uses 4 input bits. The number of distinct analog output levels it can generate is: **[1 mark]**

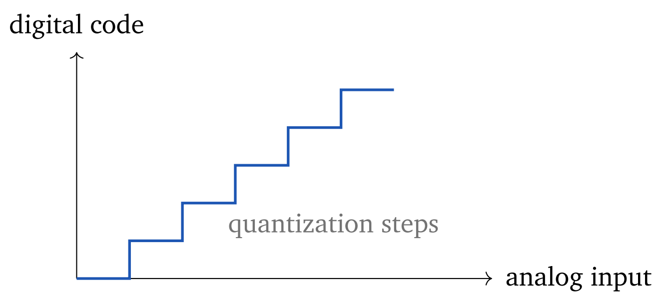
(A) 8

(B) 16

(C) 4

(D) 32

Q15. The ideal input–output staircase of an analog-to-digital converter (ADC) is sketched below. A 10-bit ADC digitises an input range of 0 to 10.24 V. Taking the number of steps as 2^{10}, the resolution (voltage per least-significant bit) is: **[1 mark]**



(A) 1 mV

(B) 5 mV

(C) 10 mV

(D) 100 mV

Q16. Which ADC architecture achieves the highest conversion speed by comparing the analog input simultaneously against a bank of $2^n - 1$ comparators in a single step? **[1 mark]**

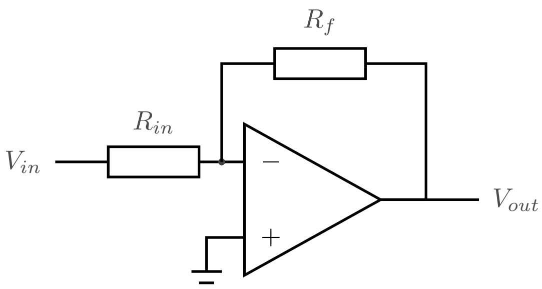
(A) flash (parallel) ADC

(B) successive-approximation ADC

(C) dual-slope integrating ADC

(D) sigma–delta ADC

Q17. For the ideal inverting operational-amplifier stage shown, $R_{in} = 5$ kΩ and $R_f = 15$ kΩ. The closed-loop voltage gain V_{out}/V_{in} is: **[1 mark]**



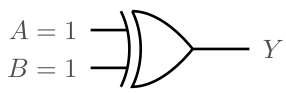
(A) $+3$

(B) $+4$

(C) -3

(D) -15

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. Rounding a continuous-amplitude sample to the nearest discrete level in an ADC introduces an unavoidable error. The noise-like signal that models this error is called: **[1 mark]**

(A) thermal (Johnson) noise

(B) aliasing

(C) flicker ($1/f$) noise

(D) quantization noise

Sensors, Bioinstrumentation and Measurements

Q20. A parallel-plate capacitive displacement sensor has capacitance $C = \frac{\varepsilon A}{d}$, where d is the plate separation. If the moving plate is pushed so that d decreases, the capacitance: **[1 mark]**

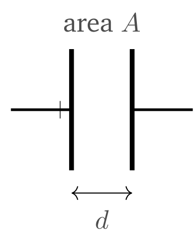
(A) increases

(B) decreases

(C) stays constant

(D) becomes zero

Q21. The parallel-plate capacitive sensor shown has plate area $A = 4$ cm^2 and air gap $d = 0.1$ mm. Using $\varepsilon_0 = 8.85 \times 10^{-12}$ F/m, the capacitance $C = \frac{\varepsilon_0 A}{d}$ is nearest to: **[2 marks]**



(A) 8.85 pF

(B) 17.7 pF

(C) 35.4 pF

(D) 354 pF

Q22. A Linear Variable Differential Transformer (LVDT) used to track valve motion has a calibrated sensitivity of 20 mV per millimetre of core displacement. For a core displacement of 2.5 mm, the magnitude of the output voltage is: **[2 marks]**

(A) 8 mV

(B) 20 mV

(C) 25 mV

(D) 50 mV

Q23. A capacitive pressure sensor's capacitance changes from 100 pF at rest to 110 pF under load. The fractional change in capacitance, $\frac{\Delta C}{C}$, expressed as a percentage of the rest value, is: **[2 marks]**

(A) 1%

(B) 10%

(C) 11%

(D) 0.1%

Q24. An inductive proximity sensor detects the approach of a nearby metallic target without contact. It does so by sensing the change in: **[2 marks]**

(A) its own capacitance

(B) its ohmic resistance only

(C) the dielectric constant of air

(D) its coil inductance caused by induced eddy currents

Q25. In an LVDT, the primary coil is flanked by two identical secondary coils connected in series opposition. When the movable ferromagnetic core sits exactly at the central (null) position, the differential output voltage is: **[2 marks]**

(A) maximum

(B) equal to the excitation voltage

(C) half the excitation voltage

(D) ideally zero (the null)

Biomedical Signal Processing

Q26. Unlike the short-time Fourier transform, which slides a window of *fixed* width, the wavelet transform analyses a biosignal using scaled and shifted copies of a mother wavelet. Its key advantage is that it provides: [2 marks]

(A) multi-resolution (variable) time–frequency analysis

(B) only the frequency content, with no time information

(C) only the time content, with no frequency information

(D) infinite frequency resolution at every scale

Q27. An ECG channel is sampled at 500 samples per second and recorded for a duration of 10 seconds. The total number of samples stored is: [2 marks]

(A) 500

(B) 5000

(C) 50

(D) 50000

Q28. An electromyogram (EMG) burst is modelled as a zero-mean sinusoid whose peak amplitude is 2 mV. The root-mean-square (RMS) value of this signal, $V_{\text{rms}} = V_{\text{peak}}/\sqrt{2}$, is: [2 marks]

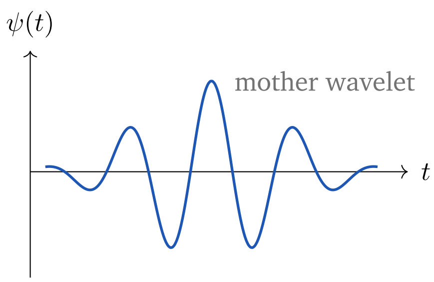
(A) 2 mV

(B) 1 mV

(C) 1.41 mV

(D) 2.83 mV

Q29. The mother wavelet sketched below is stretched or compressed by a scale parameter a before being correlated with the signal. Increasing the scale a (stretching the wavelet) makes it sensitive to: [2 marks]



(A) lower-frequency components of the signal

(B) higher-frequency components of the signal

(C) only the DC (mean) level

(D) only broadband noise

Q30. A discrete-time biosignal segment has the four samples $x[n] = \{1, 2, 2, 1\}$. Its energy $E = \sum_n x[n]^2$ is: **[2 marks]**

(A) 6

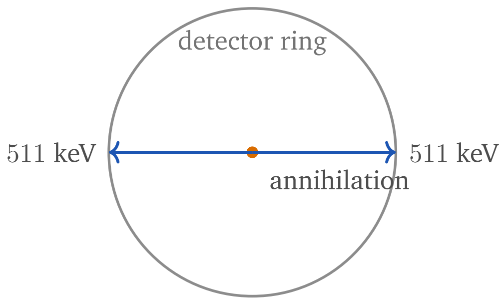
(B) 10

(C) 36

(D) 4

Medical Imaging Systems

Q31. In Positron Emission Tomography (PET), a positron annihilates with a nearby electron and produces a pair of gamma photons, each of energy 511 keV, as shown. To conserve momentum these two photons travel: **[2 marks]**



(A) in the same direction

(B) in nearly opposite directions (about $180°$ apart)

(C) at $90°$ to each other

(D) in completely random directions

Q32. The radiotracer most widely used in clinical PET imaging of tissue glucose metabolism (for example in oncology) is: **[2 marks]**

(A) technetium-99m pertechnetate

(B) iodine-131

(C) thallium-201

(D) fluorine-18 fluorodeoxyglucose (FDG)

Q33. A radioisotope used in nuclear medicine has a physical half-life of 6 hours. Starting from a fresh sample, the fraction of the original activity that remains after 18 hours is: **[2 marks]**

(A) $\frac{1}{4}$

(B) $\frac{1}{8}$

(C) $\frac{1}{6}$

(D) $\frac{1}{16}$

Q34. The gamma (Anger) camera used for planar scintigraphy and SPECT in nuclear medicine detects emitted gamma rays chiefly by means of a: **[2 marks]**

(A) silicon photodiode array alone

(B) gas-filled ionization chamber

(C) sodium iodide NaI(Tl) scintillation crystal coupled to photomultiplier tubes

(D) rotating X-ray tube

Q35. Technetium-99m, the most commonly used radionuclide in diagnostic nuclear medicine, has a physical half-life of about: **[2 marks]**

(A) 6 days

(B) 6 minutes

(C) 60 hours

(D) 6 hours

Biomechanics and Biomaterials

Q36. Poly(methyl methacrylate) (PMMA) is a rigid acrylic polymer widely used in orthopaedics and dentistry, most characteristically as: **[2 marks]**

(A) a fast-resorbing surgical suture

(B) a soft hydrogel contact lens

(C) bone cement for anchoring joint prostheses (and intraocular lenses)

(D) a metallic implant coating

Q37. Poly(lactic acid) (PLA) is favoured for resorbable fixation devices such as screws and pins because it is: **[2 marks]**

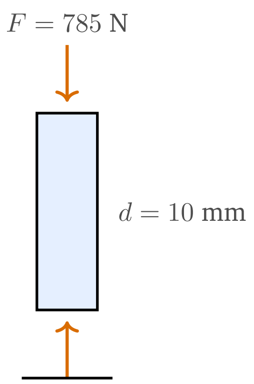
(A) biodegradable, hydrolysing to lactic acid that the body metabolises

(B) permanent and completely non-degradable in the body

(C) electrically conductive

(D) strongly ferromagnetic

Q38. A cylindrical PMMA rod of diameter 10 mm carries an axial tensile load of 785 N, as shown. Using cross-sectional area $A = \frac{\pi d^2}{4}$, the axial stress in the rod is nearest to: **[2 marks]**



(A) 2.5 MPa

(B) 5 MPa

(C) 7.85 MPa

(D) 10 MPa

Q39. A PMMA specimen with Young's modulus $E = 3$ GPa is loaded within its linear-elastic range to an axial stress of $\sigma = 30$ MPa. The axial strain produced, $\varepsilon = \sigma/E$, is: **[2 marks]**

(A) 0.1

(B) 0.01

(C) 0.001

(D) 0.0001

Q40. A biomaterial that actively bonds to living bone by growing a surface hydroxyapatite layer (for example Bioglass® 45S5) is classified as: **[2 marks]**

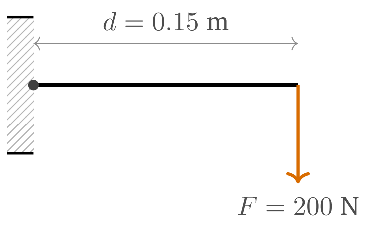
(A) bioinert

(B) bioactive

(C) biodegradable

(D) ferromagnetic

Q41. A fractured long bone is stabilised by a straight bone plate modelled as a cantilever, as shown. A transverse force $F = 200$ N acts at the free end, a horizontal distance $d = 0.15$ m from the fixation point. The bending moment $M = F\,d$ at the fixation is: **[2 marks]**



(A) 10 N·m

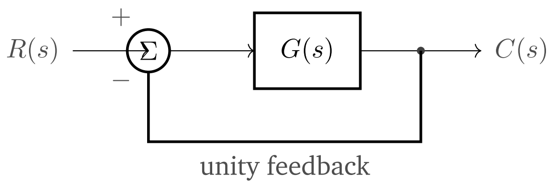
(B) 20 N·m

(C) 30 N·m

(D) 300 N·m

Control Systems and Medical Instrumentation

Q42. For the unity negative-feedback control system shown, the forward-path transfer function is $G(s)$ and the feedback path has unity gain. The overall closed-loop transfer function $\frac{C(s)}{R(s)}$ is: **[2 marks]**



(A) $G(s)$

(B) $1 + G(s)$

(C) $\frac{1}{1 + G(s)}$

(D) $\frac{G(s)}{1 + G(s)}$

Q43. In a cardiac catheter that touches the heart directly, the maximum permissible patient (leakage) current under normal conditions is kept very low to avoid microshock-induced ventricular fibrillation. This limit is of the order of: **[2 marks]**

(A) 500 mA

(B) 5 mA

(C) 100 μA

(D) 10 μA

Q44. For a 50–60 Hz macroshock current passing hand-to-hand through an intact body, the threshold at which ventricular fibrillation is likely to be triggered is generally taken to be about: **[2 marks]**

(A) 1 mA

(B) 100 mA

(C) 10 μA

(D) 10 A

Q45. The green-and-yellow protective-earth (ground) conductor of a mains-powered Class I medical device is provided mainly to: **[2 marks]**

(A) give fault current a low-resistance path so exposed metalwork stays near ground potential

(B) increase the signal-amplifier gain

(C) filter power-line noise from the signal

(D) supply the normal operating current of the device

Q46. A first-order temperature probe used in a patient monitor has a time constant $\tau = 5$ s. Following a sudden (step) change in temperature, the time the probe takes to reach about 63.2% of the final reading is: **[2 marks]**

(A) 2.5 s

(B) 5 s

(C) 10 s

(D) 3.2 s

Detailed Solutions

Q1.

Solution

Concept – pancreatic control of blood glucose: The endocrine pancreas contains the islets of Langerhans, whose two main cell types secrete opposing glucose-regulating hormones.

Step 1 – identify the two islet hormones: The beta cells secrete insulin; the alpha cells secrete glucagon.

Step 2 – match the action to the question: Insulin *lowers* blood glucose by driving glucose uptake into muscle, liver and fat.

Step 3 – confirm the secreting cell: Since insulin is the beta-cell product, the beta cells described in the question are the source.

Why the other options are wrong:

- B, glucagon: is an alpha-cell hormone that *raises* blood glucose.
- C, thyroxine: is a thyroid hormone that sets metabolic rate.
- D, cortisol: is an adrenal steroid that tends to raise blood glucose.

Final Answer: insulin $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q1

Q2.

Solution

Concept – the thyroid gland and metabolic rate: The thyroid, a butterfly-shaped gland in the neck, secretes iodine-containing hormones that control how fast cells consume energy.

Step 1 – name the hormones: Thyroxine (T_4) and triiodothyronine (T_3) are the thyroid's principal secretions.

Step 2 – link to function: These hormones raise the basal metabolic rate, oxygen consumption and heat production of tissues.

Step 3 – locate the gland: Both hormones come from the thyroid gland, which lies over the trachea in the front of the neck.

Why the other options are wrong:

- A, adrenal gland: secretes cortisol and adrenaline, not T_3/T_4.

- B, pituitary gland: secretes TSH, which *stimulates* the thyroid, but not T_3/T_4 itself.
- D, pineal gland: secretes melatonin, which governs sleep rhythm.

Final Answer: thyroid gland $\Rightarrow$ $\boxed{C}$

Answer: (C) Go Back to Q2

Q3.

Solution

Concept – protein digestion in the stomach: Digestion of protein begins in the stomach, where an acid-activated enzyme cleaves peptide bonds.

Step 1 – recall the gastric enzyme: The gastric chief cells release pepsinogen, which the stomach's hydrochloric acid converts to active pepsin.

Step 2 – note the acid requirement: Pepsin works only at the low pH (≈ 2) of the stomach; this matches the "strongly acidic environment" in the question.

Step 3 – select the enzyme: The protein-digesting, acid-loving gastric enzyme is pepsin.

Why the other options are wrong:

- A, salivary amylase: digests starch in the mouth, not protein.
- B, pancreatic lipase: digests fat in the small intestine.
- C, trypsin: also digests protein but acts in the *alkaline* small intestine, not the acidic stomach.

Final Answer: pepsin $\Rightarrow$ $\boxed{D}$

Answer: (D) Go Back to Q3

Q4.

Solution

Concept – acidity of gastric juice: The parietal cells of the stomach secrete hydrochloric acid, making the gastric lumen one of the most acidic environments in the body.

Step 1 – read the marker on the scale: The stomach marker sits near the low end of the 0–14 pH scale, well below the neutral value of 7.

Step 2 – recall the physiological value: During active digestion the gastric pH is about 1.5 to 2.

Step 3 – pick the nearest option: Of the choices, "about 2" matches this strongly acidic value.

Why the other options are wrong:

- B, about 7: is neutral, like pure water or blood plasma.
- C, about 9, and D, about 12: are alkaline, characteristic of, for example, pancreatic secretions or household bases, not gastric juice.

Final Answer: gastric pH $\approx 2 \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q4

Q5.

Solution

Concept – the adrenal stress response: The adrenal medulla releases catecholamines that prepare the body for immediate physical action.

Step 1 – identify the medullary hormone: The chief secretion of the adrenal medulla is adrenaline (epinephrine).

Step 2 – match its effects: Adrenaline raises heart rate and cardiac output, dilates the bronchial airways and mobilises glucose, the classic "fight or flight" pattern.

Step 3 – select the hormone: The stress hormone described is adrenaline (epinephrine).

Why the other options are wrong:

- B, insulin: is a pancreatic hormone that lowers blood glucose.
- C, melatonin: is a pineal hormone regulating the sleep–wake cycle.
- D, oxytocin: is a posterior-pituitary hormone acting in labour and lactation.

Final Answer: adrenaline (epinephrine) $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q5

Q6.

Solution

Concept – the liver as the body's largest gland: One abdominal organ combines exocrine (bile) and metabolic-storage functions and is the largest gland in the body.

Step 1 – match the exocrine function: Bile, which emulsifies dietary fat, is produced by the liver.

Step 2 – match the storage function: The liver also stores glucose as glycogen and releases it to buffer blood glucose.

Step 3 – select the organ: Both functions belong to the liver, the largest gland in the body.

Why the other options are wrong:

- A, pancreas: secretes digestive enzymes and hormones but does not make bile or store glycogen in bulk.
- B, spleen: is a lymphoid organ that filters blood, not a digestive gland.
- D, gall bladder: only *stores and concentrates* bile made by the liver; it does not produce bile.

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

Answer: (C) Go Back to Q6

Q7.

Solution

Concept – resonance of a series RLC circuit: $f_0 = \dfrac{1}{2\pi\sqrt{LC}}$.

Step 1 – list the data in base units: $L = 100$ mH $= 0.1$ H, $C = 10\ \mu$F $= 10 \times 10^{-6}$ F.

Step 2 – form the product LC: $LC = 0.1 \times 10 \times 10^{-6}$

$LC = 1 \times 10^{-6}$ s^2

Step 3 – take the square root: $\sqrt{LC} = \sqrt{1 \times 10^{-6}}$

$\sqrt{LC} = 1 \times 10^{-3}$ s

Step 4 – multiply by 2π: $2\pi\sqrt{LC} = 2\pi \times 10^{-3}$

$2\pi\sqrt{LC} = 6.283 \times 10^{-3}$ s

Step 5 – take the reciprocal: $f_0 = \dfrac{1}{6.283 \times 10^{-3}}$

$f_0 = 159.2$ Hz ≈ 159 Hz

Final Answer: $f_0 \approx 159$ Hz $\Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q7

Q8.

Solution

Concept – series RLC impedance at resonance: $Z = R + j\left(\omega L - \frac{1}{\omega C}\right)$.

Step 1 – apply the resonance condition: At resonance the reactances are equal: $\omega L = \frac{1}{\omega C}$.

Step 2 – cancel the reactive term: The bracket $\left(\omega L - \frac{1}{\omega C}\right)$ becomes zero, so the imaginary part of Z vanishes.

Step 3 – evaluate the impedance: $Z = R + j0 = R$, which is purely resistive.

Step 4 – classify this value: Because the reactive part is added in quadrature, $|Z| = \sqrt{R^2 + 0}$ is at its smallest here; the U-shaped curve confirms a minimum at f_0.

Why the other options are wrong:

- B: the value is correct (R) but a series-resonant impedance is a *minimum*, not a maximum.
- C, zero: would need $R = 0$, an ideal lossless circuit.
- D, infinite: describes a *parallel* (anti-resonant) tank, not a series circuit.

Final Answer: minimum, equal to $R \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q8

Q9.

Solution

Concept – output-element rule for first-order RC filters: Whether an RC pair is high-pass or low-pass depends on which element carries the output.

Step 1 – examine the low-frequency limit: At low frequency the capacitor's reactance $X_C = \frac{1}{2\pi f C}$ is very large, so most of the input voltage drops across C and little appears across R.

Step 2 – examine the high-frequency limit: At high frequency X_C becomes small, the capacitor behaves almost like a wire, and nearly all the input voltage appears across R.

Step 3 – identify the passband: The output (taken across R) is small at low frequencies and large at high frequencies, so high frequencies pass.

Step 4 – name the filter: An RC network with the output across the resistor is a high-pass filter, with $f_c = \dfrac{1}{2\pi RC}$.

Why the other options are wrong:

- A, low-pass: would take the output across the *capacitor*.
- C and D, band-pass / notch: need at least two reactive elements, not a single RC pair.

Final Answer: high-pass filter $\Rightarrow$ $\boxed{\text{B}}$

Answer: (B) Go Back to Q9

Q10.

Solution

Concept – cut-off frequency of an RL low-pass filter: $f_c = \dfrac{R}{2\pi L}$.

Step 1 – list the data in base units: $R = 2\ \text{k}\Omega = 2000\ \Omega$, $L = 100\ \text{mH} = 0.1\ \text{H}$.

Step 2 – form the denominator $2\pi L$: $2\pi L = 2\pi \times 0.1$

$2\pi L = 0.6283\ \text{H}$

Step 3 – divide: $f_c = \dfrac{2000}{0.6283}$

Step 4 – evaluate: $f_c = 3183\ \text{Hz}$

Step 5 – round: $f_c \approx 3.18\ \text{kHz}$

Why the other options are wrong:

- B, 318 Hz, and C, 31.8 kHz: are off by a factor of ten (misplaced decimal).
- D, 100 Hz: ignores the R/L ratio entirely.

Final Answer: $f_c \approx 3.18\ \text{kHz} \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q10

Q11.

Solution

Concept – quality factor and bandwidth: The quality factor measures how sharp (selective) a resonant peak is relative to its width.

Step 1 – recall the definition: Q is the ratio of the resonant (centre) frequency to the -3 dB bandwidth.

Step 2 – write the relation: $Q = \dfrac{f_0}{\text{BW}}$.

Step 3 – interpret: A large Q means a narrow bandwidth about f_0, i.e. a sharply selective circuit; a small Q means a broad, gently-peaked response.

Why the other options are wrong:

- A, BW/f_0: is the reciprocal of Q (the damping-like quantity).
- B and D: are dimensionally wrong (Q is a pure ratio of two frequencies).

Final Answer: $Q = \dfrac{f_0}{\text{BW}} \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q11

Q12.

Solution

Concept – capacitive reactance versus frequency: $X_C = \dfrac{1}{2\pi f C}$, an inverse relationship with frequency.

Step 1 – inspect the formula: Frequency f appears in the denominator.

Step 2 – reason about the trend: If a quantity is inversely proportional to f, then increasing f makes that quantity smaller.

Step 3 – state the result: As f increases, X_C decreases; at very high frequency the capacitor behaves almost like a short circuit.

Why the other options are wrong:

- A, increases with f: describes an *inductor* ($X_L = 2\pi f L$), not a capacitor.
- C, constant: would describe a resistor.
- D, infinite: is only the low-frequency (DC) limit, not the trend as f rises.

Final Answer: X_C decreases $\Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q12

Q13.

Solution

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

Step 1 – list the data in base units: $R = 1\ \text{k}\Omega = 10^3\ \Omega$, $C = 0.1\ \mu\text{F} = 0.1 \times 10^{-6}\ \text{F} = 10^{-7}\ \text{F}$.

Step 2 – substitute: $\tau = (10^3)(10^{-7})$

Step 3 – combine the powers of ten: $10^3 \times 10^{-7} = 10^{-4}$

Step 4 – write in seconds: $\tau = 10^{-4}\ \text{s}$

Step 5 – convert to milliseconds: $\tau = 10^{-4}\ \text{s} = 0.1 \times 10^{-3}\ \text{s} = 0.1\ \text{ms}$

Final Answer: $\tau = 0.1\ \text{ms} \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q13

Q14.

Solution

Concept – number of levels for an n-bit converter: An n-bit converter can represent 2^n distinct codes, hence 2^n output levels.

Step 1 – read the bit count: The DAC uses $n = 4$ bits.

Step 2 – raise two to that power: $2^4 = 2 \times 2 \times 2 \times 2$

Step 3 – evaluate: $2^4 = 16$

Step 4 – interpret: The 4-bit DAC can produce 16 distinct analog output levels (codes 0000 to 1111).

Why the other options are wrong:

- A, $8 = 2^3$: is a 3-bit converter.
- C, 4: confuses the number of bits with the number of levels.
- D, $32 = 2^5$: is a 5-bit converter.

Final Answer: 16 levels $\Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q14

Q15.

Solution

Concept – resolution (LSB voltage) of an ADC: Resolution $= \frac{\text{full-scale range}}{2^n}$.

Step 1 – list the data: Full-scale range $= 10.24$ V, number of bits $n = 10$.

Step 2 – find the number of steps: $2^{10} = 1024$.

Step 3 – divide the range by the steps: Resolution $= \frac{10.24}{1024}$

Step 4 – evaluate: Resolution $= 0.01$ V

Step 5 – convert to millivolts: 0.01 V $= 10$ mV per LSB.

Why the other options are wrong:

- A, 1 mV, and B, 5 mV: are too small; they would need many more bits over this range.
- D, 100 mV: is ten times too large (as if only ~ 100 steps).

Final Answer: 10 mV per LSB $\Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q15

Q16.

Solution

Concept – ADC architectures and speed: Converters trade speed against complexity; the fastest converts in a single clocked comparison.

Step 1 – recall the flash principle: A flash (parallel) ADC uses a resistor ladder and $2^n - 1$ comparators that all fire at once, giving the code in one step.

Step 2 – compare conversion times: Successive-approximation takes n clock cycles; dual-slope takes many cycles (it integrates); sigma–delta oversamples heavily. All are slower than flash.

Step 3 – select the fastest: The single-step, comparator-bank converter is the flash ADC.

Why the other options are wrong:

- B, successive-approximation: is moderate speed, one bit per clock.
- C, dual-slope: is slow but very accurate and noise-rejecting.
- D, sigma–delta: is slow, high-resolution, and used for audio/biopotentials.

Final Answer: flash (parallel) ADC $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q16

Q17.

Solution

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

Step 1 – list the data: $R_{in} = 5\ \text{k}\Omega$, $R_f = 15\ \text{k}\Omega$.

Step 2 – form the resistor ratio: $\frac{R_f}{R_{in}} = \frac{15\ \text{k}\Omega}{5\ \text{k}\Omega}$

$$\frac{R_f}{R_{in}} = 3$$

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

Step 4 – interpret: The output is three times the input and inverted (a 180° phase reversal).

Why the other options are wrong:

- A, $+3$: has the right magnitude but misses the inverting sign.
- B, $+4$: would be the *non-inverting* gain $1 + R_f/R_{in}$ with different values.
- D, -15: uses R_f alone and ignores R_{in}.

Final Answer: gain $= -3 \Rightarrow \boxed{\text{C}}$

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 rule: $Y = A \oplus B$, which is 1 for $A \neq B$ and 0 for $A = B$.

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

Step 3 – read the output: Because the inputs are the same, $Y = 1 \oplus 1 = 0$.

Why the other options are wrong:

- A, 1: would be the OR-gate result for these inputs, not XOR.
- B, high impedance: applies to a tri-state buffer, not a logic gate at valid

inputs.

- C, undefined: the output is well defined once both inputs are HIGH.

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

Answer: (D) Go Back to Q18

Q19.

Solution

Concept – error introduced by amplitude quantization: Mapping a continuous amplitude onto a finite set of levels rounds each sample, and the rounding error acts like added noise.

Step 1 – identify the source of error: The difference between the true sample and its nearest quantization level is the quantization error.

Step 2 – describe its statistics: Over many samples this error is small, roughly uniform between $\pm\frac{1}{2}$ LSB, and appears as a broadband, noise-like signal.

Step 3 – name it: This is called quantization noise; more bits (finer levels) reduce it.

Why the other options are wrong:

- A, thermal noise: comes from random carrier motion in resistors, not from rounding.
- B, aliasing: comes from *under-sampling* in time, a separate effect.
- C, flicker noise: is a low-frequency device noise, unrelated to level rounding.

Final Answer: quantization noise $\Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q19

Q20.

Solution

Concept – capacitance of a parallel-plate sensor: $C = \dfrac{\varepsilon A}{d}$, so C is inversely proportional to the plate separation d.

Step 1 – inspect the relation: d appears in the denominator of $C = \dfrac{\varepsilon A}{d}$.

Step 2 – reason about the change: If d becomes smaller while ε and A stay fixed, dividing by a smaller number gives a larger result.

Step 3 – state the outcome: The capacitance increases as the plates come closer together. This is the basis of a capacitive displacement/pressure sensor.

Why the other options are wrong:

- B, decreases: is the opposite trend (it happens when d *grows*).
- C, constant: ignores the dependence on d.
- D, zero: capacitance cannot vanish for a finite, non-zero gap.

Final Answer: capacitance increases $\Rightarrow$ $\boxed{\text{A}}$

Answer: (A) Go Back to Q20

Q21.

Solution

Concept – parallel-plate capacitance: $C = \dfrac{\varepsilon_0 A}{d}$ for an air gap.

Step 1 – convert the data to base SI units: $A = 4\ \text{cm}^2 = 4 \times 10^{-4}\ \text{m}^2$

$d = 0.1\ \text{mm} = 1 \times 10^{-4}\ \text{m}$

$\varepsilon_0 = 8.85 \times 10^{-12}\ \text{F/m}$

Step 2 – substitute into the formula: $C = \dfrac{(8.85 \times 10^{-12})(4 \times 10^{-4})}{1 \times 10^{-4}}$

Step 3 – simplify the area/gap ratio: $\dfrac{4 \times 10^{-4}}{1 \times 10^{-4}} = 4$

Step 4 – multiply by ε_0: $C = 8.85 \times 10^{-12} \times 4$

$C = 35.4 \times 10^{-12}\ \text{F}$

Step 5 – express in picofarads: $C = 35.4\ \text{pF}$

Why the other options are wrong:

- A, 8.85 pF, and B, 17.7 pF: drop the factor $A/d = 4$ or halve it.
- D, 354 pF: is ten times too large (a decimal-point slip in d).

Final Answer: $C \approx 35.4$ pF $\Rightarrow$ $\boxed{\text{C}}$

Answer: (C) Go Back to Q21

Q22.

Solution

Concept – linear sensor output: For a linear transducer, output = sensitivity × input.

Step 1 – list the data: Sensitivity = 20 mV/mm, displacement = 2.5 mm.

Step 2 – multiply: $V_{out} = 20\ \text{mV/mm} \times 2.5\ \text{mm}$

Step 3 – evaluate: $V_{out} = 50\ \text{mV}$

Step 4 – interpret: The LVDT gives a 50 mV output for a 2.5 mm core motion, with the phase indicating direction.

Why the other options are wrong:

- A, 8 mV: divides instead of multiplies.
- B, 20 mV: uses only the sensitivity and forgets the displacement.
- C, 25 mV: multiplies by 1.25 mm, not 2.5 mm.

Final Answer: $V_{out} = 50\ \text{mV} \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q22

Q23.

Solution

Concept – fractional (percentage) change: $\dfrac{\Delta C}{C} = \dfrac{C_{\text{new}} - C_{\text{rest}}}{C_{\text{rest}}}$.

Step 1 – find the change ΔC: $\Delta C = 110\ \text{pF} - 100\ \text{pF} = 10\ \text{pF}$.

Step 2 – divide by the rest value: $\dfrac{\Delta C}{C} = \dfrac{10\ \text{pF}}{100\ \text{pF}}$

$$\frac{\Delta C}{C} = 0.10$$

Step 3 – convert to a percentage: $0.10 \times 100\% = 10\%$

Why the other options are wrong:

- A, 1%: divides by 1000 pF instead of 100 pF.
- C, 11%: divides ΔC by the *new* value 110 pF rather than the rest value.
- D, 0.1%: is a factor-of-100 error.

Final Answer: $\dfrac{\Delta C}{C} = 10\% \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q23

Q24.

Solution

Concept – inductive proximity sensing: An energised coil generates an oscillating magnetic field; a conductive target disturbs that field.

Step 1 – describe the interaction: When a metal target enters the field, circulating eddy currents are induced in it.

Step 2 – link to the coil: These eddy currents oppose the coil's field and change the effective inductance (and losses) of the coil.

Step 3 – state what is sensed: The detection circuit reads this change in coil inductance to signal the target's presence, all without contact.

Why the other options are wrong:

- A, capacitance: is the mechanism of a *capacitive* proximity sensor, not an inductive one.
- B, resistance only: the coil's DC resistance is not the primary sensed quantity.
- C, dielectric constant of air: is irrelevant to an inductive (magnetic) sensor.

Final Answer: change of coil inductance (eddy currents) $\Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q24

Q25.

Solution

Concept – LVDT null position: The two secondaries are wound in series opposition, so their induced EMFs subtract.

Step 1 – consider the symmetric case: When the core is centred, it links equally with both secondary coils.

Step 2 – combine the secondary EMFs: The two EMFs are then equal in magnitude but opposite in sense: $V_{out} = V_{s1} - V_{s2} = 0$.

Step 3 – name this position: This is the null (balance) point; displacing the core either way unbalances the pair and produces an output whose phase gives the direction.

Why the other options are wrong:

- A, maximum: occurs at large displacement, not at the centre.
- B and C: the null output is essentially zero, not a fraction of the excitation.

Final Answer: ideally zero (the null) $\Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q25

Q26.

Solution

Concept – wavelet versus short-time Fourier transform: The wavelet transform correlates a signal with scaled (stretched/compressed) and shifted copies of a mother wavelet.

Step 1 – recall the STFT limitation: The short-time Fourier transform uses one fixed window width, forcing a single, uniform time–frequency resolution everywhere.

Step 2 – describe the wavelet's adaptivity: Small scales (compressed wavelets) give fine time resolution for fast events; large scales (stretched wavelets) give fine frequency resolution for slow trends.

Step 3 – name the benefit: This adaptive tiling of the time–frequency plane is multi-resolution analysis, well suited to transient biosignals such as ECG QRS complexes.

Why the other options are wrong:

- B and C: the wavelet transform keeps *both* time and frequency (scale) information, not just one.
- D, infinite resolution at every scale: is impossible under the time–frequency (uncertainty) trade-off.

Final Answer: multi-resolution time–frequency analysis $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q26

Q27.

Solution

Concept – total samples from rate and duration: Number of samples = sampling rate $\times$ duration.

Step 1 – list the data: Sampling rate $= 500$ samples/s, duration $= 10$ s.

Step 2 – multiply: $N = 500$ samples/s $\times$ 10 s

Step 3 – evaluate: $N = 5000$ samples

Step 4 – check the units: samples/s $\times$ s $=$ samples, so the answer is a pure sample count, 5000.

Why the other options are wrong:

- A, 500: is the number of samples in just one second.
- C, 50: divides instead of multiplies.
- D, 50000: overcounts by a factor of ten.

Final Answer: $N = 5000$ samples $\Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q27

Q28.

Solution

Concept – RMS of a sinusoid: $V_{\text{rms}} = \dfrac{V_{\text{peak}}}{\sqrt{2}}$ for a zero-mean sine wave.

Step 1 – list the data: $V_{\text{peak}} = 2$ mV.

Step 2 – substitute: $V_{\text{rms}} = \dfrac{2\text{ mV}}{\sqrt{2}}$

Step 3 – rationalise the $\sqrt{2}$: $\dfrac{2}{\sqrt{2}} = \dfrac{2}{\sqrt{2}} \cdot \dfrac{\sqrt{2}}{\sqrt{2}} = \dfrac{2\sqrt{2}}{2} = \sqrt{2}$

Step 4 – evaluate: $V_{\text{rms}} = \sqrt{2}$ mV ≈ 1.41 mV

Why the other options are wrong:

- A, 2 mV: is the peak value, not the RMS.
- B, 1 mV: would divide by 2 (that gives the average of a rectified half, not RMS).
- D, 2.83 mV: is the peak-to-peak value ($2V_{\text{peak}} \cdot \ldots$), i.e. $2\sqrt{2}$ mV, too large.

Final Answer: $V_{\text{rms}} \approx 1.41$ mV $\Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q28

Q29.

Solution

Concept – scale parameter and frequency: In the wavelet transform, the scale a dilates the mother wavelet $\psi\left(\dfrac{t}{a}\right)$.

Step 1 – relate scale to width: A large a stretches the wavelet in time, making it broad and slowly varying.

Step 2 – relate width to frequency: A broad, slowly varying waveform contains low frequencies, so it correlates best with the low-frequency content of the signal.

Step 3 – state the mapping: Increasing the scale a therefore probes lower-frequency components; decreasing a (a compressed wavelet) probes higher-frequency components.

Why the other options are wrong:

- B, higher frequencies: corresponds to *small* scale, the opposite of stretching.
- C, only DC: a wavelet has zero mean, so it cannot capture the DC level.
- D, only noise: stretched wavelets track genuine low-frequency structure, not just noise.

Final Answer: lower-frequency components $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q29

Q30.

Solution

Concept – energy of a discrete-time signal: $E = \sum_n x[n]^2$.

Step 1 – list the samples: $x[n] = \{1, 2, 2, 1\}$.

Step 2 – square each sample: $1^2 = 1$

$2^2 = 4$

$2^2 = 4$

$1^2 = 1$

Step 3 – add the squared values: $E = 1 + 4 + 4 + 1$

Step 4 – evaluate: $E = 10$

Why the other options are wrong:

- A, 6: is the sum of the samples $(1 + 2 + 2 + 1)$, not of their squares.
- C, 36: is the *square of the sum* $(6)^2$, not the sum of squares.
- D, 4: keeps only one squared term.

Final Answer: $E = 10 \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q30

Q31.

Solution

Concept – positron–electron annihilation in PET: When a positron meets an electron, both are annihilated and their combined rest energy appears as gamma photons.

Step 1 – apply conservation of energy: Each electron rest energy is 511 keV, so two photons of 511 keV are produced (total 1022 keV).

Step 2 – apply conservation of momentum: The pair is nearly at rest at annihilation, so the total momentum is almost zero; the two photons must fly off in essentially opposite directions to cancel momentum.

Step 3 – link to detection: PET exploits this by "coincidence detection": a photon pair striking two detectors about 180° apart defines a line through the annihilation site.

Why the other options are wrong:

- A, same direction: would violate momentum conservation.
- C, 90°: is not consistent with a near-zero net momentum.
- D, random: coincidence imaging relies on the fixed $\approx 180^\circ$ geometry.

Final Answer: nearly opposite ($\approx 180^\circ$) $\Rightarrow \boxed{B}$

Answer: (B) Go Back to Q31

Q32.

Solution

Concept – the standard PET metabolic tracer: Clinical PET most often images glucose uptake using a positron-emitting glucose analogue.

Step 1 – identify the positron emitter: Fluorine-18 is a positron (β^+) emitter with a convenient ~ 110 min half-life.

Step 2 – identify the carrier molecule: It is attached to deoxyglucose to form fluorodeoxyglucose (FDG), which cells take up like glucose.

Step 3 – select the tracer: The workhorse PET metabolic tracer is ^{18}F-FDG, high in metabolically active tissue such as many tumours.

Why the other options are wrong:

- A, technetium-99m: is a *gamma* emitter for SPECT/scintigraphy, not a positron emitter.

- B, iodine-131: is used for thyroid therapy/imaging, not routine PET.
- C, thallium-201: is a SPECT myocardial-perfusion agent.

Final Answer: fluorine-18 FDG $\Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q32

Q33.

Solution

Concept – radioactive decay in half-lives: After n half-lives, the surviving fraction is $\left(\frac{1}{2}\right)^n$.

Step 1 – count the half-lives elapsed: $n = \dfrac{\text{elapsed time}}{\text{half-life}} = \dfrac{18\text{ h}}{6\text{ h}}$

$n = 3$

Step 2 – apply the decay factor: Fraction remaining $= \left(\frac{1}{2}\right)^3$

Step 3 – evaluate: $\left(\frac{1}{2}\right)^3 = \frac{1}{8}$

Step 4 – interpret: After three half-lives only $\frac{1}{8}$ (12.5%) of the original activity remains.

Why the other options are wrong:

- A, $\frac{1}{4}$: is two half-lives (12 h).
- C, $\frac{1}{6}$: wrongly divides linearly instead of halving.
- D, $\frac{1}{16}$: is four half-lives (24 h).

Final Answer: $\frac{1}{8}$ remains $\Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q33

Q34.

Solution

Concept – the gamma (Anger) camera detector: Nuclear-medicine cameras convert incoming gamma photons into light and then into an electrical signal with position information.

Step 1 – absorb the gamma ray: A large thallium-activated sodium iodide, NaI(Tl), scintillation crystal absorbs each gamma photon and emits a flash of visible light (scintillation).

Step 2 – convert light to signal: An array of photomultiplier tubes (PMTs) behind the crystal senses the flash; the relative PMT signals fix the photon's position (Anger logic).

Step 3 – select the detector: The gamma camera therefore uses a NaI(Tl) scintillation crystal coupled to PMTs.

Why the other options are wrong:

- A, silicon photodiode array alone: cannot by itself stop and localise high-energy gamma rays as the crystal/PMT chain does.
- B, ionization chamber: measures dose/exposure, not spatial images.
- D, rotating X-ray tube: is the source in CT, not a nuclear-medicine detector.

Final Answer: NaI(Tl) scintillator with PMTs $\Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q34

Q35.

Solution

Concept – half-life of technetium-99m: The most-used SPECT radionuclide is chosen partly for its short, convenient physical half-life.

Step 1 – recall the standard value: Technetium-99m has a physical half-life of about 6 hours.

Step 2 – explain the suitability: Six hours is long enough to prepare and administer the tracer and complete imaging, yet short enough to limit patient dose. Its 140 keV gamma is ideal for NaI(Tl) cameras.

Step 3 – pick the matching option: The value is about 6 hours.

Why the other options are wrong:

- A, 6 days: is far too long and would raise patient dose.
- B, 6 minutes: is too short to complete routine imaging.
- C, 60 hours: is an order of magnitude too long.

Final Answer: about 6 hours $\Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q35

Q36.

Solution

Concept – clinical use of PMMA: PMMA is a hard, transparent, biocompatible acrylic used where a rigid, mouldable polymer is needed.

Step 1 – recall its orthopaedic role: In joint-replacement surgery, PMMA is mixed and cured in situ as "bone cement" to fix a prosthesis (for example a hip stem) into bone.

Step 2 – recall its ophthalmic role: Its optical clarity also makes PMMA a classic material for rigid intraocular lenses.

Step 3 – select the characteristic use: The characteristic use is as bone cement (and intraocular lenses).

Why the other options are wrong:

- A, resorbing suture: describes PLA/PGA, not the essentially permanent PMMA.
- B, hydrogel contact lens: describes soft hydrogels (for example pHEMA), not rigid PMMA.
- D, metallic coating: PMMA is a polymer, not a metal coating.

Final Answer: bone cement / intraocular lenses ⇒ $\boxed{\text{C}}$

Answer: (C) Go Back to Q36

Q37.

Solution

Concept – why PLA is used for resorbable implants: Resorbable devices must safely break down in the body after the tissue has healed.

Step 1 – recall PLA chemistry: Poly(lactic acid) is a polyester whose ester bonds are cleaved by water (hydrolysis) over weeks to months.

Step 2 – trace the degradation products: Hydrolysis yields lactic acid, a natural metabolite that the body clears through normal metabolic pathways.

Step 3 – link to the application: Because it gradually disappears, PLA needs no removal surgery, which is why it is used for resorbable screws, pins and sutures.

Why the other options are wrong:

- B, permanent: is the opposite of PLA's resorbable behaviour.
- C, electrically conductive: PLA is an insulating polymer.

- D, ferromagnetic: PLA has no magnetic response.

Final Answer: biodegradable, hydrolyses to lactic acid $\Rightarrow \boxed{A}$

Answer: (A) Go Back to Q37

Q38.

Solution

Concept – axial stress in a circular rod: $\sigma = \frac{F}{A}$ with $A = \frac{\pi d^2}{4}$.

Step 1 – convert the diameter: $d = 10$ mm $= 0.01$ m.

Step 2 – compute the cross-sectional area: $A = \frac{\pi(0.01)^2}{4}$

$A = \frac{\pi \times 1 \times 10^{-4}}{4}$

$A = 7.854 \times 10^{-5}$ m^2

Step 3 – divide the force by the area: $\sigma = \frac{785}{7.854 \times 10^{-5}}$

Step 4 – evaluate: $\sigma = 9.995 \times 10^6$ Pa

Step 5 – express in megapascals: $\sigma \approx 10$ MPa

Why the other options are wrong:

- A, 2.5 MPa, and B, 5 MPa: use too large an area (for example a wrong radius/diameter).
- C, 7.85 MPa: divides by 100 mm^2 instead of the correct area.

Final Answer: $\sigma \approx 10$ MPa $\Rightarrow \boxed{D}$

Answer: (D) Go Back to Q38

Q39.

Solution

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

Step 1 – convert to base units: $\sigma = 30$ MPa $= 30 \times 10^6$ Pa

$E = 3$ GPa $= 3 \times 10^9$ Pa

Step 2 – substitute: $\varepsilon = \frac{30 \times 10^6}{3 \times 10^9}$

Step 3 – divide the coefficients: $\frac{30}{3} = 10$

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

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

$\varepsilon = 0.01$

Why the other options are wrong:

- A, 0.1: is ten times too large (a power-of-ten slip).
- C, 0.001, and D, 0.0001: are ten and one-hundred times too small.

Final Answer: $\varepsilon = 0.01 \Rightarrow \boxed{B}$

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

Q40.

Solution

Concept – classifying biomaterials by tissue response: Biomaterials are grouped by how the body reacts to them: bioinert, bioactive or biodegradable.

Step 1 – describe the given behaviour: The material grows a surface hydroxyapatite layer and chemically *bonds* to living bone.

Step 2 – match the class: A material that forms such a direct chemical bond with tissue is called bioactive.

Step 3 – give the example: Bioglass 45S5 and certain calcium-phosphate ceramics are classic bioactive materials.

Why the other options are wrong:

- A, bioinert: (for example alumina, titanium) is tolerated but does not chemically bond to bone.
- C, biodegradable: breaks down and is resorbed rather than bonding permanently.
- D, ferromagnetic: describes a magnetic property, not a tissue-interaction class.

Final Answer: bioactive $\Rightarrow \boxed{B}$

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

Q41.

Solution

Concept – bending moment of a cantilever: $M = F\,d$, the force times its perpendicular distance from the fixation.

Step 1 – list the data: $F = 200$ N, $d = 0.15$ m.

Step 2 – multiply: $M = 200 \times 0.15$

Step 3 – evaluate: $M = 30$ N · m

Step 4 – interpret: This bending moment at the fixation point is what the bone plate (and its screws) must resist without failing.

Why the other options are wrong:

- A, 10 N · m, and B, 20 N · m: use a shorter lever arm than 0.15 m.
- D, 300 N · m: uses $d = 1.5$ m, a decimal-point error.

Final Answer: $M = 30$ N · m $\Rightarrow \boxed{\text{C}}$

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

Q42.

Solution

Concept – closed-loop gain with unity feedback: For forward gain $G(s)$ and feedback $H(s)$, $\dfrac{C}{R} = \dfrac{G}{1+GH}$; here $H = 1$.

Step 1 – write the summing-junction equation: Error $E(s) = R(s) - C(s)$ (unity negative feedback).

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

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

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

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

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

Why the other options are wrong:

- A, G: is the open-loop gain, ignoring feedback.
- B, $1 + G$: is the return difference, not the closed-loop transfer function.
- C, $\dfrac{1}{1+G}$: is the error-to-input transfer function, not the output-to-input one.

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

Answer: (D) Go Back to Q42

Q43.

Solution

Concept – microshock and leakage-current limits: A conductor in direct contact with the heart bypasses the skin's protective resistance, so even tiny currents can fibrillate the myocardium.

Step 1 – recall the microshock hazard: Currents of only tens of microamperes delivered directly to the heart can trigger ventricular fibrillation.

Step 2 – recall the safety limit: Medical-equipment standards (for example IEC 60601 for cardiac-floating applied parts) cap the patient leakage current at about $10\ \mu$A under normal conditions.

Step 3 – select the value: The order-of-magnitude limit is $10\ \mu$A.

Why the other options are wrong:

- A, 500 mA, and B, 5 mA: are enormous for an intracardiac path and would be lethal.
- C, $100\ \mu$A: is closer to macroshock-era chassis limits, still ten times above the microshock limit.

Final Answer: $\approx 10\ \mu\text{A} \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q43

Q44.

Solution

Concept – physiological effects of 50–60 Hz body current: As current through the body rises, effects progress from perception to let-go to fibrillation.

Step 1 – recall the low-current thresholds: About 1 mA is the threshold of perception; roughly 10–15 mA is the "let-go" threshold.

Step 2 – recall the fibrillation threshold: Ventricular fibrillation for a hand-to-hand macroshock is generally taken to begin at about 75–100 mA.

Step 3 – select the value: Of the options, 100 mA is the fibrillation-threshold order of magnitude.

Why the other options are wrong:

- A, 1 mA: is only the barely-perceptible level.
- C, 10 μA: is the *microshock* (intracardiac) limit, far below macroshock fibrillation.
- D, 10 A: is far above; such currents cause severe burns and cardiac arrest, not merely the fibrillation threshold.

Final Answer: ≈ 100 mA $\Rightarrow$ $\boxed{\text{B}}$

Answer: (B) Go Back to Q44

Q45.

Solution

Concept – purpose of the protective-earth conductor: The green-and-yellow earth wire is a safety (not a signal) connection in Class I equipment.

Step 1 – describe the fault scenario: If a live wire touches the metal enclosure, the exposed metal could otherwise become live and shock the user.

Step 2 – describe the earth's action: The protective earth gives that fault current a low-resistance path to ground, holding the enclosure near ground potential and driving enough current to trip the fuse/breaker.

Step 3 – state the purpose: Its role is to keep touchable metalwork safe by carrying fault current to earth.

Why the other options are wrong:

- B, increase gain: the earth wire has nothing to do with amplifier gain.
- C, filter noise: signal filtering is done by the circuit, not the safety earth.
- D, supply operating current: normal current flows in the live and neutral conductors, not the protective earth.

Final Answer: provides a fault-current path to keep metalwork near ground $\Rightarrow$ $\boxed{\text{A}}$

Answer: (A) Go Back to Q45

Q46.

Solution

Concept – step response of a first-order system: A first-order system reaches 63.2% of its final change after exactly one time constant.

Step 1 – write the step response: $y(t) = y_\infty\left(1 - e^{-t/\tau}\right)$.

Step 2 – evaluate at $t = \tau$: $y(\tau) = y_\infty\left(1 - e^{-1}\right)$

$e^{-1} = 0.368$, so $1 - e^{-1} = 0.632$

Step 3 – interpret: Thus 63.2% of the final value is reached at $t = \tau$, one time constant.

Step 4 – substitute the given value: With $\tau = 5$ s, the probe reaches 63.2% after 5 s.

Why the other options are wrong:

- A, 2.5 s: is half a time constant, only about 39% of the change.
- C, 10 s: is 2τ ($\approx 86\%$).
- D, 3.2 s: confuses the percentage figure with a time.

Final Answer: $t = \tau = 5 \text{ s} \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q46

Answer Key

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