GATE Biomedical Engineering

Sample Paper – 9

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. During vigorous exercise in a warm environment, the dominant physiological mechanism by which a healthy adult dissipates the large metabolic heat load and prevents a dangerous rise in core temperature is: **[1 mark]**

(A) conduction of heat to the surrounding still air

(B) shivering thermogenesis

(C) evaporation of sweat from the skin surface

(D) a fall in the basal metabolic rate

Q2. A common clinical rule of thumb estimates a person's age-predicted maximum heart rate as $HR_{max} = 220 - \text{age (years)}$. For a healthy 40-year-old undergoing an exercise stress test, the predicted maximum heart rate is: **[1 mark]**

(A) 220 bpm
(B) 140 bpm
(C) 40 bpm
(D) 180 bpm

Q3. During heavy exercise a trained athlete's heart rate rises to 150 beats per minute while the stroke volume increases to about 120 mL per beat. The cardiac output ($CO = HR \times SV$) at this workload is nearest to: **[1 mark]**

(A) 9 L/min
(B) 18 L/min
(C) 1.8 L/min
(D) 27 L/min

Q4. Core body temperature is held close to 37 °C by a central controller that compares thermal signals against a set point and drives sweating, shivering and vasomotor responses. The brain region that acts as this central thermostat is the: **[1 mark]**

(A) hypothalamus
(B) cerebellum
(C) medulla oblongata
(D) pituitary gland

Q5. During short bursts of very intense exercise the oxygen supply to working skeletal muscle falls short of demand, so ATP is regenerated anaerobically. The metabolic by-product that then accumulates in the muscle and blood is: **[1 mark]**

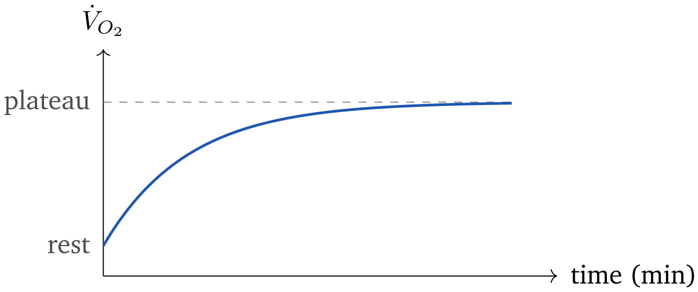
(A) stored glycogen

(B) creatine phosphate

(C) carbon dioxide only

(D) lactic acid (lactate)

Q6. The curve below shows the rise in whole-body oxygen uptake $\dot{V}_{O_2}$ at the onset of a bout of constant moderate-intensity exercise, climbing exponentially to a plateau. The plateau value reached after a few minutes represents: **[1 mark]**



(A) the resting metabolic rate before exercise

(B) the maximal oxygen uptake $\dot{V}_{O_2\,\max}$

(C) the steady-state oxygen demand of the exercise

(D) the oxygen deficit incurred at the start

Electric Circuits, Signals and Systems

Q7. For a linear time-invariant (LTI) system with impulse response $h(t)$, the zero-state output $y(t)$ produced by an arbitrary input $x(t)$ is obtained by: **[1 mark]**

(A) multiplying $x(t)$ by $h(t)$ point by point

(B) adding $x(t)$ and $h(t)$

(C) differentiating $x(t)$ with respect to $h(t)$

(D) convolving $x(t)$ with $h(t)$

Q8. The impulse response of a linear time-invariant system is defined as the output of the system when the input applied is: **[1 mark]**

(A) a unit step $u(t)$

(B) a unit impulse $\delta(t)$

(C) a unit-amplitude sinusoid

(D) a unit ramp $t\,u(t)$

Q9. Two discrete-time sequences are convolved. The input sequence $x[n]$ has 4 non-zero samples and the impulse response $h[n]$ has 3 non-zero samples. The linear convolution $y[n] = x[n] * h[n]$ has a total length of: **[1 mark]**

(A) 7 samples

(B) 12 samples

(C) 6 samples

(D) 4 samples

Q10. Using the sifting property of the unit impulse, the convolution of an arbitrary continuous-time signal $x(t)$ with the unit impulse $\delta(t)$, namely $x(t) * \delta(t)$, equals: **[1 mark]**

(A) 0

(B) $\delta(t)$

(C) $x(t)$

(D) the time derivative $\dfrac{dx(t)}{dt}$

Q11. For a linear time-invariant system, the unit-step response $s(t)$ is related to the unit-impulse response $h(t)$ by: **[1 mark]**

(A) $s(t)$ is the time derivative of $h(t)$

(B) $s(t)$ is the reciprocal of $h(t)$

(C) $s(t)$ is the Fourier transform of $h(t)$

(D) $s(t)$ is the running time integral of $h(t)$

Q12. A biopotential signal is modelled as $x(t) = \cos(100\pi t)$, with t in seconds. The fundamental period of this signal is: **[1 mark]**

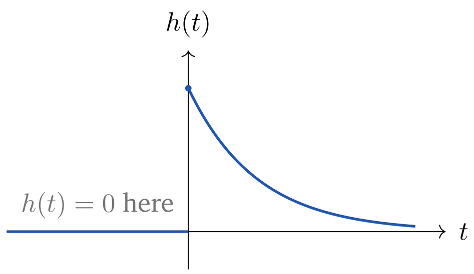
(A) 10 ms

(B) 20 ms

(C) 100 ms

(D) 50 ms

Q13. The impulse response $h(t)$ of a first-order analog circuit is sketched below. From the shape of $h(t)$, the system is causal. A continuous-time LTI system is causal if and only if its impulse response satisfies: **[1 mark]**



(A) $h(t) = 0$ for all $t < 0$

(B) $h(t) = 0$ for all $t > 0$

(C) $h(t) = 0$ for all t

(D) $h(t) = 0$ only at $t = 0$

Analog and Digital Electronics

Q14. A JK flip-flop is clocked with both inputs tied to logic HIGH, i.e. $J = K = 1$. On each active clock edge the output Q will: **[1 mark]**

(A) be set to 1 and stay there

(B) reset to 0 and stay there

(C) toggle (complement its previous state)

(D) hold its previous state unchanged

Q15. Among common integrated-circuit logic families, the one that draws essentially zero static (quiescent) current and therefore offers the lowest standby power consumption is: **[1 mark]**

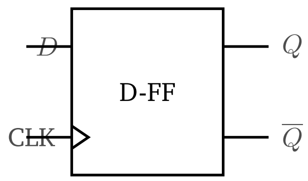
(A) standard TTL

(B) ECL (emitter-coupled logic)

(C) RTL (resistor-transistor logic)

(D) CMOS

Q16. The positive-edge-triggered D flip-flop shown samples its data input D at each rising edge of the clock. If $D = 1$ at the instant of a rising clock edge, the output Q immediately after that edge becomes: **[1 mark]**



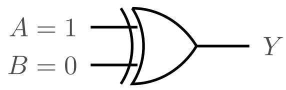
(A) 0

(B) the previous value of Q

(C) high impedance

(D) 1

Q17. For the two-input exclusive-OR (XOR) gate shown, the inputs are held at $A = 1$ and $B = 0$. The logic level at the output $Y = A \oplus B$ is: **[1 mark]**



(A) 0

(B) 1

(C) high impedance

(D) undefined

Q18. A ripple (asynchronous) counter is required to count through all states of a modulo-16 sequence, i.e. from 0 to 15 and back. The number of flip-flops needed is: **[1 mark]**

(A) 16

(B) 8

(C) 4

(D) 2

Q19. Among the standard bipolar and MOS logic families, the one that provides the highest switching speed (lowest propagation delay), at the cost of high power dissipation, is: **[1 mark]**

(A) ECL (emitter-coupled logic)

(B) CMOS

(C) standard TTL

(D) PMOS

Sensors, Bioinstrumentation and Measurements

Q20. A pulse oximeter estimates arterial oxygen saturation (SpO_2) non-invasively by measuring the differential light absorption of oxygenated and deoxygenated haemoglobin at two wavelengths. One is red light near 660 nm; the other lies in the: **[1 mark]**

(A) near-infrared band (about 940 nm)

(B) ultraviolet band

(C) green band (about 530 nm)

(D) X-ray band

Q21. A Linear Variable Differential Transformer (LVDT) used to track catheter tip displacement has a sensitivity of 20 mV per millimetre over its linear range. When the demodulated output reads 50 mV, the displacement of the core is: **[2 marks]**

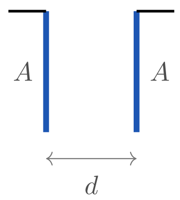
(A) 1000 mm

(B) 0.4 mm

(C) 70 mm

(D) 2.5 mm

Q22. A capacitive displacement sensor is built from two parallel plates separated by an air gap, with capacitance $C = \dfrac{\varepsilon A}{d}$, where d is the plate spacing. If a measured displacement halves the plate spacing d while the plate area A stays fixed, the capacitance: **[2 marks]**



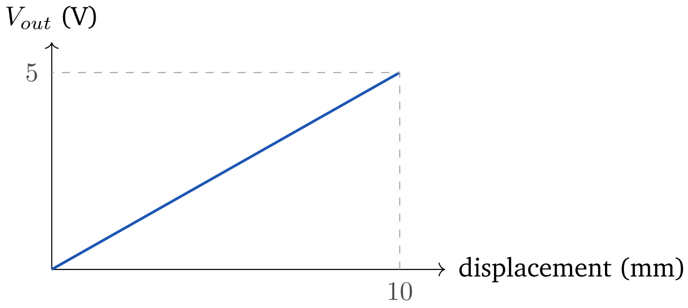
(A) doubles

(B) halves

(C) is unchanged

(D) quadruples

Q23. The transfer characteristic of a linear potentiometric (resistive) displacement transducer is plotted below: the output voltage rises linearly from 0 to 5 V as the wiper moves through its full travel of 0 to 10 mm. The sensitivity of the transducer, read as the slope of the line, is: **[2 marks]**



(A) 2 V/mm

(B) 5 V/mm

(C) 0.5 V/mm

(D) 50 V/mm

Q24. Photoplethysmography and pulse oximetry rely on a light-sensing element that produces an electrical output in proportion to the intensity of the light falling on it. The optical sensor most commonly used for this purpose is a photodiode, which converts: **[2 marks]**

(A) an electrical current into emitted light

(B) mechanical pressure into a voltage

(C) temperature into a change of resistance

(D) incident light into an electrical current

Q25. An optical incremental rotary encoder is fitted to the shaft of a rehabilitation robot joint and produces 360 pulses for one complete 360° revolution of the shaft. The angular resolution of the encoder (smallest angular change it can resolve) is: **[2 marks]**

(A) 360°

(B) 0.5°

(C) 1°

(D) 10°

Biomedical Signal Processing

Q26. Heart-rate variability (HRV) analysis quantifies the beat-to-beat fluctuation of the heart rhythm. The time series from which all standard HRV metrics are computed is the sequence of: **[2 marks]**

(A) successive P-wave durations

(B) successive R-R (inter-beat) intervals

(C) successive QRS amplitudes

(D) successive T-wave areas

Q27. An HRV recording has a mean R-R (normal-to-normal) interval of 800 ms. The corresponding mean heart rate, obtained from $\text{HR} = \dfrac{60}{\text{R-R in seconds}}$, is: **[2 marks]**

(A) 75 bpm

(B) 80 bpm

(C) 60 bpm

(D) 125 bpm

Q28. In frequency-domain HRV analysis the R-R interval spectrum is split into bands. The high-frequency (HF) band, spanning roughly 0.15 to 0.4 Hz, is generally accepted as a marker predominantly of: **[2 marks]**

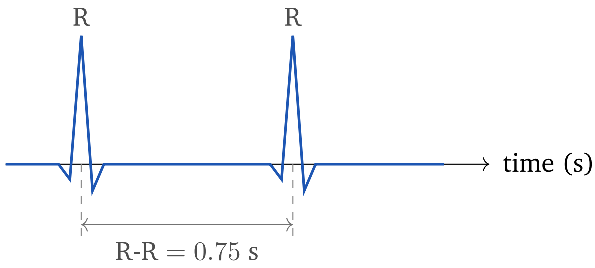
(A) parasympathetic (vagal) activity

(B) sympathetic activity only

(C) power-line interference

(D) electrode motion artifact

Q29. Two consecutive R peaks of an ECG are shown with the R-R interval marked as 0.75 s. The instantaneous heart rate computed from this single interval is: **[2 marks]**



(A) 45 bpm

(B) 100 bpm

(C) 80 bpm

(D) 75 bpm

Q30. A widely used time-domain HRV index is SDNN, the standard deviation of all normal-to-normal (R-R) intervals in a recording. A markedly higher value of SDNN indicates: **[2 marks]**

(A) lower overall variability of the heart rhythm

(B) the presence of tachycardia

(C) a perfectly fixed, metronomic heart rate

(D) greater overall heart-rate variability

Medical Imaging Systems

Q31. Radiation dosimetry in medical imaging distinguishes several quantities. The SI unit of *absorbed dose*, defined as one joule of energy deposited per kilogram of matter, is the: **[2 marks]**

(A) sievert (Sv)

(B) becquerel (Bq)

(C) gray (Gy)

(D) roentgen (R)

Q32. To improve radiographic contrast in gastrointestinal studies, a radiopaque (positive) contrast medium is introduced so that the tract stands out against surrounding soft tissue. The agent conventionally swallowed for an upper-GI barium study is: **[2 marks]**

(A) barium sulfate suspension

(B) plain water

(C) room air

(D) sodium chloride solution

Q33. During a radiographic exposure, 0.02 J of X-ray energy is absorbed uniformly by 10 kg of tissue. The absorbed dose, defined as energy deposited per unit mass, is: **[2 marks]**

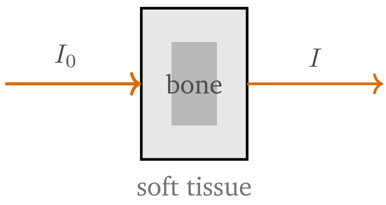
(A) 0.2 Gy

(B) 20 mGy

(C) 2 mGy

(D) 0.02 Gy

Q34. A monoenergetic X-ray beam passes through a body region containing both bone and soft tissue, as shown, and the transmitted beam forms the radiograph. The image contrast between bone and soft tissue arises fundamentally from: **[2 marks]**



(A) differences in tissue temperature

(B) differences in tissue elasticity

(C) differences in the sound speed of the tissues

(D) differences in X-ray attenuation between bone and soft tissue

Q35. To capture the biological impact of a given exposure, radiation protection uses a dose quantity that weights the absorbed dose by the relative biological effectiveness of the radiation type and is expressed in sieverts. This quantity is the: **[2 marks]**

(A) absorbed dose

(B) equivalent dose

(C) exposure

(D) activity

Biomechanics and Biomaterials

Q36. In tissue engineering, cells are seeded onto an engineered support structure. The primary intended function of this scaffold is to: **[2 marks]**

(A) deliver a continuous electric current to the seeded cells

(B) act as a permanent load-bearing metallic implant

(C) sterilise the surrounding host tissue

(D) provide a temporary three-dimensional template for cell attachment, growth and new-tissue formation

Q37. For a scaffold intended to regenerate a segment of tissue and then disappear, a key material requirement is that it should be: **[2 marks]**

(A) chemically inert and permanent in the body

(B) biodegradable, so that it is gradually resorbed and replaced by newly formed natural tissue

(C) completely non-porous to block cell ingrowth

(D) cytotoxic to the seeded cells

Q38. A porous tissue-engineering scaffold has a total (bulk) volume of 2.0 cm^3, of which the interconnected void (pore) space measures 1.6 cm^3. The porosity, defined as void volume divided by total volume, is: **[2 marks]**

(A) 20%

(B) 80%

(C) 40%

(D) 160%

Q39. A biomaterial such as hydroxyapatite or bioactive glass forms a direct chemical bond with adjacent bone and stimulates new bone growth at its surface. On the basis of tissue response, such a material is classified as: **[2 marks]**

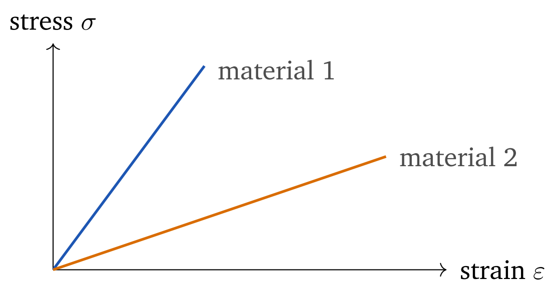
(A) bioactive

(B) bioinert

(C) toxic

(D) ferromagnetic

Q40. The initial (linear-elastic) portions of the stress–strain curves of two candidate scaffold materials are compared below. The material whose curve has the *steeper* slope in this region has the higher: **[2 marks]**



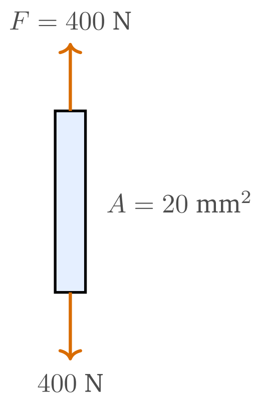
(A) porosity

(B) Young's modulus (stiffness)

(C) fracture toughness

(D) mass density

Q41. A ligament graft of uniform cross-sectional area 20 mm^2 carries a purely axial tensile force of 400 N along its length, as shown. The average normal (tensile) stress in the graft, $\sigma = F/A$, is: **[2 marks]**



(A) 20 MPa

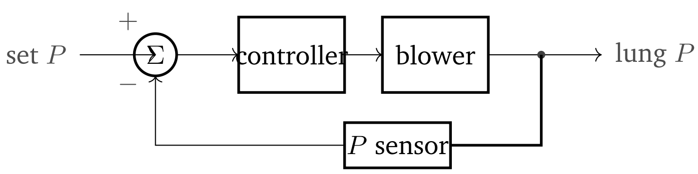
(B) 200 MPa

(C) 2 MPa

(D) 8000 Pa

Control Systems and Medical Instrumentation

Q42. A modern mechanical ventilator continuously measures the delivered airway pressure, subtracts it from the clinician-set target pressure, and drives the blower to reduce the error, as sketched. This mode of operation is an example of: **[2 marks]**



(A) negative (closed-loop) feedback control

(B) purely open-loop control

(C) positive feedback control

(D) feedforward control with no measurement

Q43. A ventilator delivers a tidal volume of 500 mL at a set respiratory rate of 12 breaths per minute. The minute ventilation, $\dot{V}_E = V_T \times f$, delivered to the patient is: **[2 marks]**

(A) 12 L/min

(B) 6 L/min

(C) 0.5 L/min

(D) 60 L/min

Q44. On a volume-controlled ventilator the clinician sets the inspiratory-to-expiratory (I:E) timing. For an adult receiving routine mechanical ventilation, the conventional I:E ratio, allowing adequate time for passive exhalation, is about: **[2 marks]**

(A) $2 : 1$

(B) $1 : 2$

(C) $1 : 1$

(D) $5 : 1$

Q45. A ventilator regulates airway pressure with a PID controller. To drive the steady-state pressure error to zero (so the delivered pressure settles exactly on the set point), the term chiefly responsible is the: **[2 marks]**

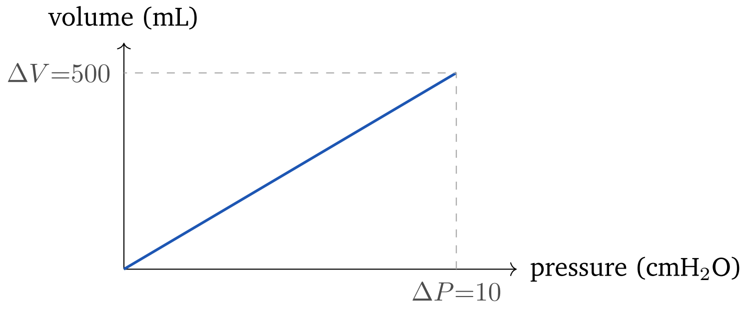
(A) integral term

(B) proportional term

(C) derivative term

(D) pure transport dead-time

Q46. During a ventilator breath the airway pressure is raised by $\Delta P = 10$ cmH_2O to deliver a volume of $\Delta V = 500$ mL to the lung, as indicated by the pressure–volume relation shown. The respiratory-system compliance, $C = \Delta V/\Delta P$, is: **[2 marks]**



(A) 5000 mL/cmH_2O

(B) 50 mL/cmH_2O

(C) 0.02 mL/cmH_2O

(D) 5 mL/cmH_2O

Detailed Solutions

Q1.

Solution

Concept – routes of heat loss during exercise: The body sheds heat by radiation, conduction, convection and evaporation; their relative shares depend on the environment and the metabolic load.

Step 1 – estimate the heat load: Vigorous exercise raises metabolic heat production several-fold, so a large amount of heat must be removed quickly.

Step 2 – consider a warm environment: When the surrounding air is warm, the skin-to-air temperature gradient is small, so radiation, conduction and convection become weak.

Step 3 – identify the dominant route: Evaporation of sweat removes the latent heat of vaporisation (about 2.4 MJ per kg of sweat) from the skin, and stays effective even when the air is warm.

Why the other options are wrong:

- A, conduction to still air: air is a poor conductor and carries away little heat.
- B, shivering: is a heat-*generating* response used in the cold, not for cooling.
- D, a fall in metabolic rate: does not happen during exercise; metabolism rises.

Final Answer: evaporation of sweat $\Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q1

Q2.

Solution

Concept – age-predicted maximum heart rate: A common clinical estimate is $\text{HR}_{\text{max}} = 220 - \text{age}$ (age in years).

Step 1 – list the data: Age $= 40$ years.

Step 2 – substitute into the formula: $\text{HR}_{\text{max}} = 220 - 40$

Step 3 – subtract: $\text{HR}_{\text{max}} = 180$ bpm.

Why the other options are wrong:

- A, 220 bpm: is the constant in the formula, not the result.
- B, 140 bpm: would need $220 - 140 = 80$, i.e. an 80-year-old.

- C, 40 bpm: is simply the age, not a heart rate.

Final Answer: $HR_{max} = 180$ bpm $\Rightarrow$ D

Answer: (D) Go Back to Q2

Q3.

Solution

Concept – cardiac output during exercise: $CO = HR \times SV$.

Step 1 – list the data: $HR = 150$ beats/min, $SV = 120$ mL/beat.

Step 2 – multiply: $CO = 150 \times 120$

$CO = 18000$ mL/min

Step 3 – convert to litres: $CO = \frac{18000}{1000}$ L/min

$CO = 18$ L/min

Step 4 – sense check: Resting cardiac output is about 5 L/min, so a rise to roughly 18 L/min during heavy exercise is physiologically reasonable.

Final Answer: $CO = 18$ L/min $\Rightarrow$ B

Answer: (B) Go Back to Q3

Q4.

Solution

Concept – central control of body temperature: Thermoregulation is coordinated by a central integrator that compares body temperature signals with a set point.

Step 1 – identify the integrator: The hypothalamus (chiefly the preoptic area) receives central and peripheral temperature information.

Step 2 – describe its output: It drives sweating and skin vasodilation to lose heat, and shivering and vasoconstriction to conserve heat, holding core temperature near 37 °C.

Why the other options are wrong:

- B, cerebellum: coordinates movement and balance.
- C, medulla oblongata: controls cardiovascular and respiratory reflexes, not the temperature set point.
- D, pituitary gland: is an endocrine effector controlled by the hypothalamus, not the thermostat itself.

Final Answer: hypothalamus ⇒ A

Answer: (A) Go Back to Q4

Q5.

Solution

Concept – anaerobic metabolism in muscle: When oxygen delivery cannot meet demand, muscle regenerates ATP by anaerobic glycolysis.

Step 1 – identify the pathway: Glucose is broken down to pyruvate without oxygen.

Step 2 – find the end product: To keep glycolysis running, pyruvate is reduced to lactic acid (lactate), which accumulates in muscle and blood.

Step 3 – link to fatigue: The associated rise in hydrogen-ion concentration contributes to the sensation of muscle fatigue during intense effort.

Why the other options are wrong:

- A, glycogen: is a stored fuel that is consumed, not produced.
- B, creatine phosphate: is used up to buffer ATP early in exercise, not accumulated.
- C, carbon dioxide only: is the product of *aerobic* metabolism, which is limited here.

Final Answer: lactic acid ⇒ D

Answer: (D) Go Back to Q5

Q6.

Solution

Concept – oxygen-uptake kinetics at exercise onset: At the start of constant exercise, $\dot{V}_{O_2}$ rises with a first-order (exponential) time course towards a new steady level.

Step 1 – read the plateau: The curve climbs and levels off; the flat plateau is the value maintained once uptake matches consumption.

Step 2 – interpret the plateau physically: At the plateau, oxygen uptake exactly equals the oxygen cost (demand) of that constant workload, so the system is in steady state.

Step 3 – distinguish it from $\dot{V}_{O_2\,\max}$: This is a submaximal, moderate bout, so the plateau is the demand of *this* exercise, well below the maximal ceiling $\dot{V}_{O_2\,\max}$.

Why the other options are wrong:

- A, resting rate: is the low starting value before the rise.
- B, $\dot{V}_{O_2\,\max}$: is reached only at maximal, not moderate, effort.
- D, oxygen deficit: is the shortfall *under* the curve during the transient rise, not the plateau.

Final Answer: steady-state oxygen demand $\Rightarrow$ $\boxed{\text{C}}$

Answer: (C) Go Back to Q6

Q7.

Solution

Concept – input-output relation of an LTI system: A linear time-invariant system is completely characterised by its impulse response $h(t)$.

Step 1 – state the governing operation: For any input $x(t)$, the zero-state output is the convolution $y(t) = x(t) * h(t) = \int_{-\infty}^{\infty} x(\tau)\, h(t-\tau)\, d\tau$.

Step 2 – justify the operation: Superposition (linearity) plus time invariance means the response is the sum of shifted, scaled impulse responses, which is exactly convolution.

Why the other options are wrong:

- A, multiplying: point-wise multiplication happens in the frequency domain, not the time domain.
- B, adding: addition is not how a system transforms an input.
- C, differentiating: only special systems differentiate; it is not the general rule.

Final Answer: convolving $x(t)$ with $h(t)$ $\Rightarrow$ $\boxed{\text{D}}$

Answer: (D) Go Back to Q7

Q8.

Solution

Concept – definition of the impulse response: The impulse response is the fingerprint of an LTI system.

Step 1 – apply the definition: $h(t)$ is the output measured when the input is the Dirac unit impulse $\delta(t)$, with the system initially at rest.

Step 2 – why the impulse: Because the impulse contains all frequencies equally, the response to it reveals the complete system behaviour, from which any other output follows by convolution.

Why the other options are wrong:

- A, unit step: gives the *step* response (the integral of $h(t)$).
- C, sinusoid: gives the frequency response at one frequency only.
- D, ramp: gives the ramp response, the double integral of $h(t)$.

Final Answer: a unit impulse $\delta(t) \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q8

Q9.

Solution

Concept – length of a linear convolution: If $x[n]$ has L samples and $h[n]$ has M samples, then $y[n] = x[n] * h[n]$ has $L + M - 1$ samples.

Step 1 – list the lengths: $L = 4$ (input), $M = 3$ (impulse response).

Step 2 – add the lengths: $L + M = 4 + 3 = 7$

Step 3 – subtract one: length $= 7 - 1 = 6$ samples.

Why the other options are wrong:

- A, 7: forgets the -1 overlap term.
- B, 12: is the product 4×3, which is not how convolution length works.
- D, 4: is just the input length.

Final Answer: 6 samples $\Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q9

Q10.

Solution

Concept – impulse as the identity of convolution: The unit impulse acts as the neutral element for convolution.

Step 1 – write the sifting property: $x(t) * \delta(t) = \int_{-\infty}^{\infty} x(\tau)\,\delta(t-\tau)\,d\tau.$

Step 2 – evaluate the integral: The impulse $\delta(t-\tau)$ picks out the value of x at $\tau = t$, giving $x(t)$.

Step 3 – state the result: $x(t) * \delta(t) = x(t)$; convolving with $\delta(t)$ leaves the signal unchanged.

Why the other options are wrong:

- A, 0: would require a null system, not an impulse.
- B, $\delta(t)$: is the impulse itself, not the recovered signal.
- D, derivative: results from convolving with $\delta'(t)$, the impulse's derivative.

Final Answer: $x(t) * \delta(t) = x(t) \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q10

Q11.

Solution

Concept – step response versus impulse response: The unit step is the running integral of the unit impulse, and LTI systems preserve this relation between their responses.

Step 1 – recall the input relation: $u(t) = \int_{-\infty}^{t} \delta(\lambda)\,d\lambda.$

Step 2 – carry it through the system: Because integration is a linear time-invariant operation, the response to $u(t)$ is the integral of the response to $\delta(t)$: $s(t) = \int_{-\infty}^{t} h(\lambda)\,d\lambda.$

Step 3 – state the result: The step response is the running (cumulative) time integral of the impulse response.

Why the other options are wrong:

- A, derivative: reverses the relation; $h(t) = ds/dt$, not the other way round.
- B, reciprocal: has no basis in LTI theory.
- C, Fourier transform: gives the frequency response, a different quantity.

Final Answer: running time integral of $h(t) \Rightarrow \boxed{D}$

Answer: (D) Go Back to Q11

Q12.

Solution

Concept – period of a cosine: For $x(t) = \cos(\omega t)$, the angular frequency is ω, the frequency is $f = \omega/2\pi$, and the period is $T = 1/f$.

Step 1 – read the angular frequency: $\omega = 100\pi$ rad/s.

Step 2 – find the frequency: $f = \frac{\omega}{2\pi} = \frac{100\pi}{2\pi} = 50$ Hz.

Step 3 – find the period: $T = \frac{1}{f} = \frac{1}{50} = 0.02$ s.

Step 4 – convert to milliseconds: $T = 0.02 \times 1000 = 20$ ms.

Why the other options are wrong:

- A, 10 ms: corresponds to 100 Hz.
- C, 100 ms: corresponds to 10 Hz.
- D, 50 ms: corresponds to 20 Hz.

Final Answer: $T = 20$ ms $\Rightarrow \boxed{B}$

Answer: (B) Go Back to Q12

Q13.

Solution

Concept – causality of an LTI system: A causal system cannot respond before the input is applied.

Step 1 – link causality to $h(t)$: Since $h(t)$ is the response to an impulse applied at $t = 0$, a causal system can produce no output before that instant.

Step 2 – state the condition: Therefore $h(t) = 0$ for all $t < 0$.

Step 3 – match the sketch: The plotted $h(t)$ is exactly zero for negative time and decays for $t \geq 0$, so it is causal.

Why the other options are wrong:

- B, $h(t) = 0$ for $t > 0$: would mean the response exists only before the input, which is impossible.
- C, $h(t) = 0$ for all t: describes a dead (zero) system.

- D, zero only at $t = 0$: is not the causality condition.

Final Answer: $h(t) = 0$ for $t < 0 \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q13

Q14.

Solution

Concept – JK flip-flop truth table: The JK flip-flop's next state depends on J and K at the active clock edge.

Step 1 – recall the four cases: $J{=}0, K{=}0$ hold; $J{=}0, K{=}1$ reset to 0; $J{=}1, K{=}0$ set to 1; $J{=}1, K{=}1$ toggle.

Step 2 – apply $J = K = 1$: The toggle condition applies, so $Q_{\text{next}} = \overline{Q}$.

Step 3 – interpret: On every clock pulse the output flips $0 \to 1 \to 0 \ldots$, which is how a JK flip-flop divides the clock frequency by two.

Why the other options are wrong:

- A, set to 1: needs $J{=}1, K{=}0$.
- B, reset to 0: needs $J{=}0, K{=}1$.
- D, hold: needs $J{=}0, K{=}0$.

Final Answer: the output toggles $\Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q14

Q15.

Solution

Concept – static power in logic families: Standby (static) current flows even when a gate is not switching, and it differs greatly between families.

Step 1 – examine a CMOS gate: In either steady logic state one of the complementary MOSFETs is off, so essentially no direct current path exists from supply to ground.

Step 2 – conclude on static power: CMOS therefore draws almost zero quiescent current; its power is consumed mainly during switching transitions.

Why the other options are wrong:

- A, TTL: has a resistive path that draws steady current.

- B, ECL: keeps transistors partly conducting, giving high static power.
- C, RTL: also dissipates standing current through its resistors.

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

Answer: (D) Go Back to Q15

Q16.

Solution

Concept – operation of a D flip-flop: A D (data) flip-flop copies its input to the output at the active clock edge and then holds it.

Step 1 – apply the edge rule: On a rising clock edge, $Q_{\text{next}} = D$.

Step 2 – substitute the given input: $D = 1$ at the edge, so Q becomes 1.

Step 3 – note the hold: Until the next rising edge, Q stays at 1 regardless of changes in D.

Why the other options are wrong:

- A, 0: would require $D = 0$ at the edge.
- B, previous Q: a D flip-flop overwrites the old value; it does not hold it through a clock edge.
- C, high impedance: a flip-flop output is a driven logic level, never tri-stated by itself.

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

Answer: (D) Go Back to Q16

Q17.

Solution

Concept – exclusive-OR logic: The XOR output is 1 only when the two inputs differ.

Step 1 – write the rule: $Y = A \oplus B$; $Y = 1$ if $A \neq B$, and $Y = 0$ if $A = B$.

Step 2 – substitute the inputs: $A = 1$ and $B = 0$ are unequal.

Step 3 – evaluate: $Y = 1 \oplus 0 = 1$.

Why the other options are wrong:

- A, 0: would need equal inputs, e.g. $A = B = 1$.

- C, high impedance: an XOR output is always a defined logic level.
- D, undefined: the XOR truth table gives a definite value for every input.

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

Answer: (B) Go Back to Q17

Q18.

Solution

Concept – states of an n-bit counter: An n-flip-flop binary counter cycles through 2^n distinct states.

Step 1 – set the requirement: A modulo-16 counter needs 16 distinct states.

Step 2 – solve $2^n = 16$: $2^4 = 16$, so $n = 4$.

Step 3 – state the result: Four flip-flops are required.

Why the other options are wrong:

- A, 16: confuses the number of states with the number of flip-flops.
- B, 8: gives $2^8 = 256$ states, far more than needed.
- D, 2: gives only $2^2 = 4$ states.

Final Answer: 4 flip-flops $\Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q18

Q19.

Solution

Concept – speed of logic families: Propagation delay sets the maximum switching speed, and it differs across families.

Step 1 – consider ECL: Emitter-coupled logic keeps its transistors in the active region and switches a small current, avoiding deep saturation.

Step 2 – link to speed: Because the transistors never saturate, storage delay is minimal and ECL achieves the lowest propagation delay (highest speed).

Step 3 – note the trade-off: This speed comes at the price of high static power dissipation.

Why the other options are wrong:

- B, CMOS: is low-power but slower than ECL.

- C, TTL: saturates its transistors, adding storage delay.
- D, PMOS: is among the slowest of the MOS families.

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

Answer: (A) Go Back to Q19

Q20.

Solution

Concept – two-wavelength pulse oximetry: Oxygenated and deoxygenated haemoglobin absorb red and infrared light differently.

Step 1 – recall the two wavelengths: A pulse oximeter uses red light at about 660 nm and infrared light at about 940 nm.

Step 2 – justify the pairing: Deoxyhaemoglobin absorbs more red light while oxyhaemoglobin absorbs more infrared, so the ratio of the two absorbances gives SpO_2.

Step 3 – pick the second wavelength: The partner to the red LED is a near-infrared source around 940 nm.

Why the other options are wrong:

- B, ultraviolet: is strongly absorbed and can damage tissue; not used.
- C, green: is used in some wrist heart-rate monitors but not for the standard SpO_2 ratio.
- D, X-ray: is ionising radiation, unrelated to optical oximetry.

Final Answer: near-infrared (≈ 940 nm) $\Rightarrow$ $\boxed{\text{A}}$

Answer: (A) Go Back to Q20

Q21.

Solution

Concept – sensitivity of a displacement transducer: Displacement equals output divided by sensitivity, $x = V_o/S$.

Step 1 – list the data: Sensitivity $S = 20$ mV/mm, output $V_o = 50$ mV.

Step 2 – form the ratio: $x = \dfrac{V_o}{S} = \dfrac{50 \text{ mV}}{20 \text{ mV/mm}}$

Step 3 – divide: $x = 2.5$ mm.

Why the other options are wrong:

- A, 1000 mm: multiplies instead of dividing.
- B, 0.4 mm: inverts the ratio (20/50).
- C, 70 mm: adds the two numbers, which is meaningless.

Final Answer: $x = 2.5$ mm $\Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q21

Q22.

Solution

Concept – parallel-plate capacitive sensor: $C = \frac{\varepsilon A}{d}$, so capacitance is inversely proportional to plate spacing d.

Step 1 – write the two cases: Original: $C_1 = \frac{\varepsilon A}{d}$. New spacing $d' = d/2$: $C_2 = \frac{\varepsilon A}{d/2}$.

Step 2 – simplify the new value: $C_2 = \frac{\varepsilon A}{d/2} = \frac{2\varepsilon A}{d}$.

Step 3 – take the ratio: $\frac{C_2}{C_1} = \frac{2\varepsilon A/d}{\varepsilon A/d} = 2$, so the capacitance doubles.

Why the other options are wrong:

- B, halves: would require $C \propto d$, the wrong dependence.
- C, unchanged: ignores the change in d.
- D, quadruples: would need $C \propto 1/d^2$.

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

Answer: (A) Go Back to Q22

Q23.

Solution

Concept – sensitivity as the slope of a linear transfer curve: Sensitivity $S = \frac{\Delta V_{out}}{\Delta(\text{displacement})}$.

Step 1 – read two points from the line: At displacement 0 mm, $V_{out} = 0$ V; at 10 mm, $V_{out} = 5$ V.

Step 2 – compute the change in output: $\Delta V_{out} = 5 - 0 = 5$ V.

Step 3 – compute the change in displacement: $\Delta x = 10 - 0 = 10$ mm.

Step 4 – take the slope: $S = \dfrac{5 \text{ V}}{10 \text{ mm}} = 0.5$ V/mm.

Why the other options are wrong:

- A, 2 V/mm: inverts the ratio (10/5).
- B, 5 V/mm: uses only the numerator.
- D, 50 V/mm: multiplies instead of dividing.

Final Answer: $S = 0.5$ V/mm $\Rightarrow$ C

Answer: (C) Go Back to Q23

Q24.

Solution

Concept – photodiode transduction: A photodiode is an optical-to-electrical transducer.

Step 1 – describe the mechanism: Incident photons create electron-hole pairs in the depletion region, producing a photocurrent proportional to the light intensity.

Step 2 – identify input and output: Input is light (optical power); output is an electrical current.

Step 3 – match to the application: In pulse oximetry and photoplethysmography, the photodiode senses the transmitted or reflected light and turns it into a measurable current.

Why the other options are wrong:

- A, current into light: describes a light-emitting diode, the opposite device.
- B, pressure into voltage: describes a piezoelectric sensor.
- C, temperature into resistance: describes a thermistor or RTD.

Final Answer: light into an electrical current $\Rightarrow$ D

Answer: (D) Go Back to Q24

Q25.

Solution

Concept – resolution of an incremental encoder: Angular resolution equals the full circle divided by the number of pulses per revolution.

Step 1 – list the data: Full revolution $= 360^\circ$, pulses per revolution $= 360$.

Step 2 – form the ratio: resolution $= \dfrac{360^\circ}{360 \text{ pulses}}$

Step 3 – divide: resolution $= 1^\circ$ per pulse.

Why the other options are wrong:

- A, 360°: is a whole turn, not the smallest step.
- B, 0.5°: would need 720 pulses per revolution.
- D, 10°: would need only 36 pulses per revolution.

Final Answer: 1° per pulse $\Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q25

Q26.

Solution

Concept – basis of HRV analysis: Heart-rate variability describes how the interval between consecutive heartbeats fluctuates over time.

Step 1 – identify the beat marker: The sharp R peak of the QRS complex is the most reliable, easily detected landmark of each beat.

Step 2 – form the time series: The times between successive R peaks form the R-R (inter-beat) interval series, also called the NN series for normal beats.

Step 3 – link to the metrics: All standard time-domain (SDNN, RMSSD) and frequency-domain HRV measures are computed from this R-R interval series.

Why the other options are wrong:

- A, P-wave durations: measure atrial conduction, not beat-to-beat timing.
- C, QRS amplitudes: reflect voltage, not rhythm variability.
- D, T-wave areas: relate to repolarisation, not inter-beat intervals.

Final Answer: successive R-R intervals $\Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q26

Q27.

Solution

Concept – heart rate from the mean R-R interval: $\text{HR} = \dfrac{60}{\text{R-R interval in seconds}}$.

Step 1 – convert the interval to seconds: $\text{R-R} = 800 \text{ ms} = 0.8$ s.

Step 2 – substitute: $\text{HR} = \dfrac{60}{0.8}$

Step 3 – divide: $\text{HR} = 75$ bpm.

Why the other options are wrong:

- B, 80 bpm: corresponds to 0.75 s, not 0.8 s.
- C, 60 bpm: corresponds to a 1.0 s interval.
- D, 125 bpm: mistakenly uses 0.48 s.

Final Answer: $\text{HR} = 75 \text{ bpm} \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q27

Q28.

Solution

Concept – physiological meaning of HRV frequency bands: The R-R spectrum is divided into very-low-, low- and high-frequency bands, each linked to autonomic activity.

Step 1 – locate the HF band: The high-frequency band spans about 0.15 to 0.4 Hz.

Step 2 – link it to physiology: HF power is synchronised with respiration (respiratory sinus arrhythmia) and is mediated mainly by the vagus nerve.

Step 3 – name the branch: Vagal control is the parasympathetic branch of the autonomic nervous system.

Why the other options are wrong:

- B, sympathetic only: sympathetic influence is slower and appears mainly in the low-frequency range.
- C, power-line interference: is a $50/60$ Hz artifact, far outside the HRV band.
- D, motion artifact: is noise to be removed, not a physiological HRV marker.

Final Answer: parasympathetic (vagal) activity $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q28

Q29.

Solution

Concept – instantaneous heart rate from one R-R interval: $\text{HR} = \dfrac{60}{\text{R-R interval in seconds}}$.

Step 1 – read the interval: From the trace, R-R $= 0.75$ s.

Step 2 – substitute: $\text{HR} = \dfrac{60}{0.75}$

Step 3 – divide: $\text{HR} = 80$ bpm.

Why the other options are wrong:

- A, 45 bpm: corresponds to about 1.33 s.
- B, 100 bpm: corresponds to 0.6 s.
- D, 75 bpm: corresponds to 0.8 s, not 0.75 s.

Final Answer: $\text{HR} = 80 \text{ bpm} \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q29

Q30.

Solution

Concept – SDNN as a measure of overall variability: SDNN is the standard deviation of the normal-to-normal (R-R) intervals, so it grows when the intervals spread out more.

Step 1 – interpret a large standard deviation: A large SDNN means the R-R intervals scatter widely about their mean.

Step 2 – translate to physiology: Widely varying intervals mean the heart rhythm changes a lot from beat to beat, i.e. high heart-rate variability, usually a sign of healthy autonomic flexibility.

Why the other options are wrong:

- A, lower variability: is the opposite; low variability gives a *small* SDNN.
- B, tachycardia: is a fast mean rate, not a spread of intervals.
- C, fixed heart rate: would give SDNN near zero.

Final Answer: greater heart-rate variability $\Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q30

Q31.

Solution

Concept – SI unit of absorbed dose: Absorbed dose is the energy deposited by radiation per unit mass of matter.

Step 1 – state the definition: 1 gray = 1 joule per kilogram (1 Gy = 1 J/kg).

Step 2 – match to the quantity: Because the question defines energy per unit mass, the unit is the gray (Gy).

Why the other options are wrong:

- A, sievert: is the unit of *equivalent* (biologically weighted) dose, not absorbed dose.
- B, becquerel: measures radioactive *activity* (decays per second).
- D, roentgen: is an old unit of *exposure* (ionisation in air), not absorbed dose.

Final Answer: gray (Gy) $\Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q31

Q32.

Solution

Concept – positive radiographic contrast agents: A positive contrast medium has a high atomic number, so it attenuates X-rays strongly and appears bright on the radiograph.

Step 1 – identify the GI agent: For upper gastrointestinal studies the patient swallows a barium sulfate suspension.

Step 2 – explain the effect: Barium ($Z = 56$) sharply increases attenuation, so the coated GI tract stands out against the surrounding soft tissue, improving contrast.

Why the other options are wrong:

- B, water: has attenuation close to soft tissue and gives little contrast.
- C, air: is a *negative* contrast agent (it lowers attenuation), used differently.
- D, sodium chloride solution: is nearly tissue-equivalent and not radiopaque.

Final Answer: barium sulfate suspension $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q32

Q33.

Solution

Concept – absorbed dose: $D = \dfrac{\text{energy absorbed}}{\text{mass}}$, with 1 Gy $= 1$ J/kg.

Step 1 – list the data: Energy $= 0.02$ J, mass $= 10$ kg.

Step 2 – substitute: $D = \dfrac{0.02 \text{ J}}{10 \text{ kg}}$

Step 3 – divide: $D = 0.002$ J/kg $= 0.002$ Gy.

Step 4 – convert to milligray: $D = 0.002 \times 1000 = 2$ mGy.

Why the other options are wrong:

- A, 0.2 Gy: is $100\times$ too large.
- B, 20 mGy: is $10\times$ too large.
- D, 0.02 Gy: forgets to divide by the 10 kg mass.

Final Answer: $D = 2 \text{ mGy} \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q33

Q34.

Solution

Concept – origin of X-ray image contrast: A radiograph maps how strongly each path through the body attenuates the beam.

Step 1 – write the attenuation law: Along each ray, $I = I_0 e^{-\mu x}$, so transmission depends on the linear attenuation coefficient μ.

Step 2 – compare the two tissues: Bone has a much higher μ (dense, high effective atomic number, calcium) than soft tissue, so it transmits far fewer X-rays.

Step 3 – link to contrast: The difference in transmitted intensity between the bone path and the soft-tissue path is exactly what creates the light-and-dark contrast on the image.

Why the other options are wrong:

- A, temperature: X-ray attenuation does not depend on tissue temperature.
- B, elasticity: is relevant to elastography, not plain radiography.
- C, sound speed: governs ultrasound imaging, not X-rays.

Final Answer: differences in X-ray attenuation $\Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q34

Q35.

Solution

Concept – dose quantities in radiation protection: Equivalent dose weights the absorbed dose by a radiation-weighting factor to reflect biological harm.

Step 1 – write the relation: $H_T = w_R D_T$, where D_T is the absorbed dose (in gray) and w_R is the radiation-weighting factor.

Step 2 – identify the unit: The result H_T is expressed in sieverts (Sv).

Step 3 – name the quantity: A dose that is weighted for biological effectiveness and measured in sieverts is the equivalent dose.

Why the other options are wrong:

- A, absorbed dose: is unweighted and measured in gray.
- C, exposure: measures ionisation of air, in coulomb per kilogram.
- D, activity: measures the decay rate of a source, in becquerel.

Final Answer: equivalent dose $\Rightarrow \boxed{\text{B}}$

Answer: (B) **Go Back to Q35**

Q36.

Solution

Concept – role of a scaffold in tissue engineering: Tissue engineering combines cells, signals and a scaffold to regenerate tissue.

Step 1 – state the scaffold's job: The scaffold provides a temporary three-dimensional framework onto which seeded cells attach, spread and proliferate.

Step 2 – describe its fate: As cells lay down their own extracellular matrix, the scaffold guides the shape of the new tissue and is meant to be resorbed over time.

Why the other options are wrong:

- A, deliver electric current: is not the general purpose of a scaffold.
- B, permanent metallic implant: describes a prosthesis, the opposite of a resorbable scaffold.
- C, sterilise tissue: is not a scaffold function.

Final Answer: temporary 3D template for cell attachment and growth $\Rightarrow \boxed{\text{D}}$

Answer: (D) **Go Back to Q36**

Q37.

Solution

Concept – biodegradability of scaffolds: An ideal regenerative scaffold disappears as new tissue forms.

Step 1 – state the requirement: The scaffold should be biodegradable, breaking down at a rate matched to new-tissue formation.

Step 2 – explain why: As the scaffold resorbs, load and function transfer gradually to the growing natural tissue, leaving no foreign material behind.

Step 3 – add the supporting properties: It should also be biocompatible, porous and interconnected to allow cell ingrowth and nutrient transport.

Why the other options are wrong:

- A, inert and permanent: prevents replacement by natural tissue.
- C, non-porous: blocks cell migration and nutrient flow.
- D, cytotoxic: would kill the very cells it is meant to support.

Final Answer: biodegradable, replaced by new tissue $\Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q37

Q38.

Solution

Concept – porosity of a scaffold: porosity $= \dfrac{\text{void volume}}{\text{total volume}} \times 100\%$.

Step 1 – list the data: Void volume $= 1.6$ cm^3, total volume $= 2.0$ cm^3.

Step 2 – form the ratio: porosity $= \dfrac{1.6}{2.0}$

Step 3 – divide: porosity $= 0.8$

Step 4 – express as a percentage: porosity $= 0.8 \times 100\% = 80\%$.

Why the other options are wrong:

- A, 20%: is the solid fraction $(0.4/2.0)$, not the void fraction.
- C, 40%: mistakenly uses $0.8/2.0$.
- D, 160%: multiplies rather than divides and cannot exceed 100%.

Final Answer: porosity $= 80\% \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q38

Q39.

Solution

Concept – classification of biomaterials by tissue response: Biomaterials are grouped as bioinert, bioactive or bioresorbable according to how the body reacts to them.

Step 1 – describe the behaviour given: The material bonds chemically to bone and stimulates new bone growth at its surface.

Step 2 – assign the class: A material that forms such a direct interfacial bond and elicits a favourable biological response is bioactive (for example hydroxyapatite and bioactive glass).

Why the other options are wrong:

- B, bioinert: provokes little or no interfacial bonding (e.g. alumina, titanium oxide).
- C, toxic: would harm the tissue, the opposite of the described response.
- D, ferromagnetic: is a magnetic property, unrelated to tissue bonding.

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

Answer: (A) Go Back to Q39

Q40.

Solution

Concept – slope of the elastic region: In the linear-elastic region, stress is proportional to strain, $\sigma = E\varepsilon$, and the slope of the σ–ε line is the Young's modulus E.

Step 1 – read the two curves: Material 1 rises steeply; material 2 rises more gently for the same strain axis.

Step 2 – interpret the steeper slope: A steeper slope means a larger σ/ε ratio, hence a larger Young's modulus.

Step 3 – state the meaning: A larger E means the material is stiffer, deforming less under a given stress.

Why the other options are wrong:

- A, porosity: is not read from the elastic slope.
- C, toughness: is the area under the whole curve to fracture, not the slope.
- D, density: is a mass property, unrelated to the σ–ε slope.

Final Answer: higher Young's modulus (stiffness) $\Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q40

Q41.

Solution

Concept – axial (normal) stress: $\sigma = \dfrac{F}{A}$, with F the axial force and A the cross-sectional area.

Step 1 – convert the area to SI units: $A = 20\ \text{mm}^2 = 20 \times 10^{-6}\ \text{m}^2 = 2 \times 10^{-5}\ \text{m}^2$.

Step 2 – list the force: $F = 400$ N.

Step 3 – substitute: $\sigma = \dfrac{400}{2 \times 10^{-5}}$

Step 4 – divide: $\sigma = 2 \times 10^7$ Pa

Step 5 – express in megapascal: $\sigma = 20 \times 10^6$ Pa $= 20$ MPa.

Why the other options are wrong:

- B, 200 MPa: is $10\times$ too high (area handled as 2 mm^2).
- C, 2 MPa: is $10\times$ too low.
- D, 8000 Pa: multiplies instead of dividing by the area.

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

Answer: (A) Go Back to Q41

Q42.

Solution

Concept – closed-loop (feedback) control: A control system is closed-loop when it measures its own output and uses the error to correct itself.

Step 1 – trace the ventilator loop: The set pressure is compared with the measured lung pressure; the difference (error) drives the controller and blower.

Step 2 – identify the sign: The measured pressure is *subtracted* from the set point ($+$ and $-$ at the summing junction), so the loop reduces the error.

Step 3 – classify: Subtracting the fed-back output to shrink the error is negative feedback (closed-loop) control.

Why the other options are wrong:

- B, open-loop: uses no measurement of the output, but here pressure is measured.

- C, positive feedback: would add the output and grow the error, causing instability.
- D, feedforward only: acts before an error appears and does not use the output measurement.

Final Answer: negative (closed-loop) feedback $\Rightarrow \boxed{A}$

Answer: (A) Go Back to Q42

Q43.

Solution

Concept – minute ventilation: $\dot{V}_E = V_T \times f$, tidal volume times respiratory rate.

Step 1 – list the data: $V_T = 500$ mL, $f = 12$ breaths/min.

Step 2 – multiply: $\dot{V}_E = 500 \times 12$

$\dot{V}_E = 6000$ mL/min

Step 3 – convert to litres: $\dot{V}_E = \frac{6000}{1000} = 6$ L/min.

Why the other options are wrong:

- A, 12 L/min: would need a 1000 mL tidal volume.
- C, 0.5 L/min: ignores the respiratory rate.
- D, 60 L/min: is off by a factor of ten.

Final Answer: $\dot{V}_E = 6$ L/min $\Rightarrow \boxed{B}$

Answer: (B) Go Back to Q43

Q44.

Solution

Concept – inspiratory-to-expiratory (I:E) ratio: The I:E ratio sets how the breath cycle is split between inspiration and expiration.

Step 1 – recall exhalation physiology: Expiration is passive and slower than inspiration, so it needs a longer share of the cycle.

Step 2 – state the conventional value: For routine adult ventilation the I:E ratio is about $1 : 2$ (expiration roughly twice as long as inspiration).

Step 3 – note the reason: This longer expiratory time allows the lungs to empty and helps avoid gas trapping.

Why the other options are wrong:

- A, $2:1$: is an inverse ratio used only in special cases, not routine care.
- C, $1:1$: leaves too little expiratory time for most patients.
- D, $5:1$: is far outside physiological practice.

Final Answer: $1:2 \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q44

Q45.

Solution

Concept – role of the integral term in a PID controller: Each PID term shapes the response differently: proportional, integral and derivative.

Step 1 – describe the integral action: The integral term accumulates the error over time and keeps adjusting the output as long as any error remains.

Step 2 – link to steady-state error: Because it only stops changing when the accumulated error is driven to zero, the integral term forces the steady-state pressure error to zero.

Why the other options are wrong:

- B, proportional term: leaves a finite steady-state offset by itself.
- C, derivative term: reacts to the rate of change and improves damping, not steady-state accuracy.
- D, transport dead-time: is a delay that harms, not helps, control.

Final Answer: the integral term $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q45

Q46.

Solution

Concept – respiratory-system compliance: Compliance is the volume delivered per unit change in pressure, $C = \frac{\Delta V}{\Delta P}$, and equals the slope of the pressure–volume line.

Step 1 – list the data: $\Delta V = 500$ mL, $\Delta P = 10$ cmH_2O.

Step 2 – substitute: $C = \dfrac{500 \text{ mL}}{10 \text{ cmH}_2\text{O}}$

Step 3 – divide: $C = 50$ mL/cmH_2O.

Step 4 – sense check: A normal adult respiratory-system compliance is of the order of 50–100 mL/cmH_2O, so the value is physiologically reasonable.

Why the other options are wrong:

- A, 5000 mL/cmH_2O: multiplies instead of dividing.
- C, 0.02 mL/cmH_2O: inverts the ratio.
- D, 5 mL/cmH_2O: is off by a factor of ten.

Final Answer: $C = 50$ mL/cm$H_2O \Rightarrow \boxed{B}$

Answer: (B) Go Back to Q46

Answer Key

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