Roll No.											

PRESIDENCY UNIVERSITY

BENGALURU

End - Term Examinations – May / June 2026

Date: 27-05-2026 **Time:** 01:00pm – 04:00pm

School: SOE	**Program:** B. Tech. in ECE	
Course Code: ECE3035	**Course Name:** Biomedical Signal Processing	
Semester: VI	**Max Marks**: 100	**Weightage**: 50%

CO - Levels	**CO1**	**CO2**	**CO3**	**CO4**	**CO5**	**CO6**
Marks	**24**	**24**	**14**	**14**	**12**	**12**

Instructions:

(i) Read all questions carefully and answer accordingly.

(ii) Do not write anything on the question paper other than roll number.

Part A

Answer ALL the Questions. Each question carries 2marks. **10Q x 2M=20M**

1.	Explain the goal of parametric modelling in biomedical systems, and state one example of a biosignal (ECG, EEG, or EMG) to which it can be applied.	**2 Marks**	**L2**	**CO6**
2.	Sketch the block diagram of the Pan-Tompkins algorithm for R-peak detection from raw ECG.	**2 Marks**	**L2**	**CO5**
3.	Describe the role of the primary input signal and the reference input signal in an adaptive noise canceller. What is the desired output of the system?	**2 Marks**	**L2**	**CO4**
4.	State the primary goal of a Wiener filter and list the two statistical quantities required to design it in the frequency domain	**2 Marks**	**L2**	**CO4**
5.	Locate the DFT index (k) at which 60 Hz power line interference will appear, given an ECG signal sampled at 500 Hz and a 1000-point DFT is taken.	**2 Marks**	**L3**	**CO3**
6.	Write the general difference equation relating the input $x(n)$ and output $y(n)$ for the given digital notch filter transfer function.	**2 Marks**	**L2**	**CO3**

	$$H(z) = \frac{1 - 2\cos(\omega_0)z^{-1} + z^{-2}}{1 - 2r\cos(\omega_0)z^{-1} + r^2 z^{-2}}$$			
7.	Describe the function of the Wilson Central Terminal (WCT) within a 12-lead ECG system.	**2 Marks**	**L2**	**CO2**
8.	List two common noise sources in EEG signal acquisition, and describe how each one influences the recording quality.	**2 Marks**	**L1**	**CO2**
9.	List the standard amplitude and frequency ranges expected in a diagnostic-quality Electrooculogram (EOG) signal.	**2 Marks**	**L1**	**CO1**
10.	Define causality in recorded physiological signals and explain why all recorded biosignals are considered causal.	**2 Marks**	**L2**	**CO1**

Part B

Answer the Questions. **Total Marks 80M**

11.	**a.**	**In a 12-lead ECG setup, the instantaneous electrode potentials (in mV) are: $R_A = -0.1$, $L_A = +0.4$, $L_L = +0.7$; chest electrodes $V_1 = 0.6$, $V_2 = 0.8$, $V_3 = 1.1$, $V_4 = 1.3$, $V_5 = 1.2$, $V_6 = 1.0$. Calculate i) bipolar limb leads (Lead I, II, III) ii) Wilson Central Terminal (WCT) iii) augmented leads (aVR, aVL, aVF) iv) precordial leads (V_1–V_6 w.r.t. WCT) v) verify Einthoven's law.**	**10 Marks**	**L3**	**CO1**
	b.	**A healthy neuron has intracellular $[K^+]_{in} = 140$ mM and extracellular $[K^+]_{out} = 4$ mM at body temperature $T = 310$K; gas constant $R = 8.314$J/mol·K and Faraday constant $F = 96485$C/mol. Calculate i) Nernst potential for K^+ii) new value if $[K^+]_{out} = 8$ mM and comment on excitability.**	**10 Marks**	**L3**	**CO1**
		Or			
12.	**a.**	**During ECG analysis, the R–R interval is 0.75 s. Calculate i) heart rate (BPM) ii) state the physiological significance of the R–R interval iii) interpret the result with respect to normal adult resting range (60–100 BPM).**	**10 Marks**	**L3**	**CO1**
	b.	**In a 12-lead ECG setup, the instantaneous electrode potentials (in mV) are: $R_A = -0.3$, $L_A = +0.2$, $L_L = +0.5$; chest electrodes $V_1 = 0.4$, $V_2 = 0.6$, $V_3 = 0.9$, $V_4 = 1.1$, $V_5 = 1.0$, $V_6 = 0.8$. Calculate i) bipolar limb leads ii) WCT iii) augmented leads iv) precordial leads v) verify Einthoven's law.**	**10 Marks**	**L3**	**CO1**

13.	**a.**	**An EEG signal has average power (μV^2) in frequency bands: Delta = 18, Theta = 12, Alpha = 40, Beta = 10. Calculate i) total power (1–30 Hz) ii) relative power (%) of each band iii) identify dominant rhythm and corresponding physiological state.**	**10 Marks**	**L3**	**CO2**
	b.	**A surface EMG signal (mV) over 10 samples is: [0.3, −0.6, 0.7, −0.9, 1.1, −0.8, 0.6, −0.5, 0.4, −0.3]; activation threshold = 0.7. Calculate i) rectified signal ii) 3-point moving average envelope ($z[n] = (y[n-1] + y[n] + y[n+1])/3$) iii) sample at which activation begins.**	**10 Marks**	**L3**	**CO2**
		Or			
14.	**a.**	**An arterial pressure transducer is calibrated as 1 mV = 100 mmHg. The recorded signal for one cardiac cycle is: Time t_1: Signal = 1.5 mV, Time t_2: Signal = 13.0 mV, Time t_3: Signal = 6.5 mV; where t_1 corresponds to end of diastole, t_2 to systolic peak, and t_3 to the dicrotic notch. Calculate i) systolic and diastolic pressures ii) pulse pressure iii) mean arterial pressure (MAP).**	**10 Marks**	**L3**	**CO2**
	b.	**In a 12-lead ECG, net QRS voltages are Lead I = +8 mm and Lead aVF = +6 mm. Calculate i) mean electrical QRS axis (degrees) ii) classify the axis.**	**10 Marks**	**L3**	**CO2**

15.	**a.**	**Design a first-order analog low-pass Butterworth filter with cutoff frequency $f_c = 1$ kHz. Convert it to a digital IIR filter using the Impulse Invariance method with sampling frequency $f_s = 8$ kHz. (a) Find $H(s)$ (b) Find $h[n]$ (c) Find $H(z)$ (d) Write the difference equation.**	**10 Marks**	**L3**	**CO3**
	b.	**For an adaptive noise canceller with primary input $d(n)$, reference $x(n)$, filter output $y(n) = w(n)x(n)$, error $e(n) = d(n) - y(n)$, and LMS update $w(n+1) = w(n) + 2\mu e(n)x(n)$ with $\mu = 0.01$, compute $y(0), e(0), w(1)$ and $y(1), e(1), w(2)$ given $d(0) = 2.2, x(0) = 0.2, w(0) = 0, d(1) = 2.1, x(1) = 0.2$.**	**10 Marks**	**L3**	**CO4**
		Or			
16.	**a.**	**Design a 2nd-order IIR notch filter $H(z) = \frac{1-2\cos\omega_0 z^{-1}+z^{-2}}{1-2r\cos\omega_0 z^{-1}+r^2 z^{-2}}$ with $r = 0.95$ to remove 50 Hz interference from an ECG sampled at 500 Hz. Given $\omega_0 = 2\pi f_0/F_s, f_0 = 50, F_s = 500$, compute ω_0, write the difference equation, and find $y(0), y(1), y(2)$ for $x(n) = \sin(2\pi \cdot 10 \cdot n/500) + 0.5\sin(2\pi \cdot 50 \cdot n/500)$ with initial conditions $y(-1) = y(-2) = 0, x(-1) = x(-2) = 0$.**	**10 Marks**	**L3**	**CO3**

	b.	**Design a 2-tap Wiener filter $h = [h_0, h_1]$ to estimate clean ECG $s[n]$ from noisy measurement $x[n]$, given $x = [2, 4, 3]$ and $s = [1, 3, 2]$.**	**10 Marks**	**L3**	**CO4**

17.	**a.**	**Apply Pan-Tompkins algorithm: derivative $y[n] = x[n] - x[n-1]$, squaring $z[n] = y[n]^2$, moving window integration $w[n] = \frac{z[n]+z[n-1]+z[n-2]}{3}$ with window length 3, to filtered ECG $x[1..5] = [0.02, 0.10, 0.85, 0.15, 0.03]$ mV and $x[0] = 0.01$. Compute $y[2..5], z[2..5], w[4], w[5]$, and detect QRS peaks using fixed threshold 0.10 $(mV)^2$.**	**10 Marks**	**L3**	**CO5**
	b.	**An EEG signal is modeled as $x[n] = 0.8x[n-1] - 0.5x[n-2] + w[n]$ with $\sigma_w^2 = 0.25$. Given $x[0] = 1.2, x[1] = 0.8, x[2] = 0.5, x[3] = 0.3$, compute predicted values $\hat{x}[2], \hat{x}[3], \hat{x}[4]$ and prediction errors $w[2], w[3]$.**	**10 Marks**	**L4**	**CO6**
		Or			
18.	**a.**	**Apply Pan-Tompkins algorithm: derivative y[n]=x[n]-x[n-1], squaring z[n]=y[n]^2, moving window integration w[n]=(z[n]+z[n-1]+z[n-2])/3 with window length 3, to filtered ECG x[1..5]=[0.01, 0.05, 0.80, 0.20, 0.04] mV and x[0]=0.00. Compute y[2..5], z[2..5], w[4], w[5], and detect QRS peaks using fixed threshold 0.08 $(mV)^2$.**	**10 Marks**	**L3**	**CO5**
	b.	**Fit an AR(1) model $x[n] = -a_1 x[n-1] + w[n]$ to Heart Rate Variability (HRV) data $x[1] = 2, x[2] = 1, x[3] = -1$ by solving for a_1.**	**10 Marks**	**L4**	**CO6**