

1) $n = 8$ or 12

$$0 < f_s < 100 \text{ Hz}$$

$$V_{\max} = +5 \text{ V}$$

$$V_{\min} = -5 \text{ V}$$

$$E(t) = 1.5 \sin \pi t + 20 \sin 32\pi t - 3 \sin(60\pi t + \frac{\pi}{4})$$

Frequencies: $0.5, 16, 30 \text{ Hz}$

Amplitudes: $1.5, 20, 3 \text{ V}$

Amplitude range: $\pm (1.5 + 20 + 3) = \pm 24.5 \text{ V}$

$$\text{Gain} = \frac{V_{\text{out}}}{V_{\text{in}}}$$

$$= \frac{5}{24.5}$$

$$= \frac{10}{49}$$

$$\approx 0.2$$

$$1) \text{8-bit quantisation error} = \frac{10}{2^8}$$

$$= \frac{5}{128}$$

$$\approx 39.1 \text{ mV}$$

$$12\text{-bit quantisation error} = \frac{10}{2^{12}}$$

$$= \frac{5}{2048}$$

$$\approx 2.44 \text{ mV}$$

$$8\text{-bit relative quantisation error} = \frac{\text{Quantisation error}}{\text{GA}}$$

$$= \frac{39.1 \times 10^{-3}}{0.2(24.5)}$$

$$= 0.78125\%$$

$$\approx 0.8\%$$

$$12\text{-bit relative quantisation error} = \frac{\text{Quantisation error}}{\text{GA}}$$

$$= \frac{2.44 \times 10^{-3}}{0.2(24.5)}$$

$$= 0.048829125\%$$

$$\approx 0.05\%$$

$$2) \text{ Sensitivity : } K = \frac{\Delta V_{\text{out}}}{\Delta V_{\text{in}}}$$

$$= \frac{1 - (-1)}{25 - (-25)}$$

$$= 0.04 \text{ V cm H}_2\text{O}^{-1}$$

$$\text{A/D resolution, } Q_{\text{res}} = \frac{10}{2^{10}}$$

$$= \frac{5}{512}$$

$$\approx 9.77 \text{ mV}$$

$$\Delta V_{\text{in}} = \frac{Q_{\text{res}}}{K}$$

$$= \frac{9.77 \times 10^{-3}}{0.04}$$

$$= \frac{125}{512}$$

$$\approx 0.244 < 0.25 \text{ cmH}_2\text{O}$$

Not using an amplifier is fine, but using a gain of 5 will make the resolution better.

$$\Delta V_{\text{in}} = \frac{Q_{\text{res}}}{GK}$$

$$= \frac{9.77 \times 10^{-3}}{5 \times 0.04}$$

$$= \frac{25}{512}$$

$$\approx 0.0488 < 0.25 \text{ cmH}_2\text{O}$$

$$2) \text{ Signal frequency, } f_{\text{in}} = \frac{1}{T} \\ = \frac{1}{0.5} \\ = 2 \text{ Hz}$$

For 8 sensors and $f_s > 2f_{\text{max}}$,

$$f_s > 2(8 \times 2) \\ f_s > 32 \text{ Hz}$$

\therefore The minimum frequency is 32 Hz.

$$3) \text{ No. of steps} = \frac{5 - (-5)}{5 \times 10^3}$$

$$= 2000$$

$$\text{Bits required} = \frac{\ln 2000}{\ln 2}$$

$$= 10.46578428$$

$$\approx 11$$

Since 11-bit ADCs are not available,
a 12-bit ADC is required.