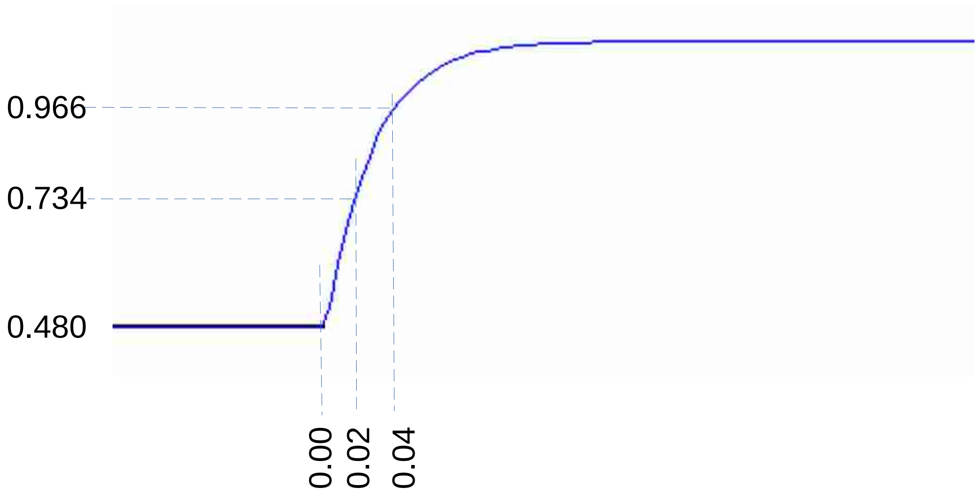
**Transducers and Instrumentation for Physiological Measurement**

Mid Term-I, 16th Feb, 2021

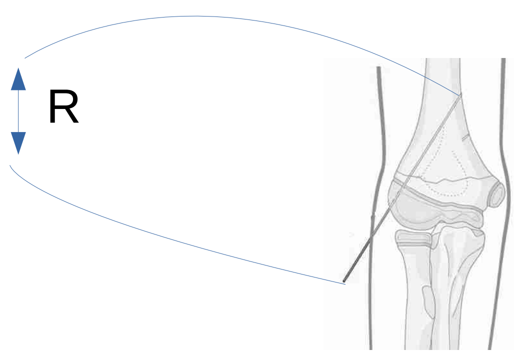
1. A temperature sensor is used to measure temperature during an experiment. The static calibration fits the equation: $V = 0.01T - 2.5$ where $\boldsymbol{V}$ is in volts and $\boldsymbol{T}$ is in Kelvin. During dynamic calibration, the sensor is initially kept at room temperature (25°C) and suddenly dipped into boiling water; the response is shown in the following diagram. The horizontal values are in seconds and the vertical values in volts.




a) Assuming that this is a first order response, what is the time constant, $\tau$, of the sensing system?

b) What is the transfer function of this system? Plot the frequency response (magnitude and phase).

2. Fixing fractures is often done using K-wires as shown in the figure here. It is important to know the tension in the wire so that correct force is applied on the fracture boundary. We will assume that the resistivity of the tissue is large compared to the wire. The length of the wire is 100mm, the radius is 0.56mm. The resistivity of the material is $400\,x\,10^{-6}\,\Omega.m$ and its Young's modulus is $1\,x\,10^{9}\,Pa$. When the wire is under tension, the resistance is measured to be $R = 40.8\,\Omega$.




a) What is the tensile force on the wire?

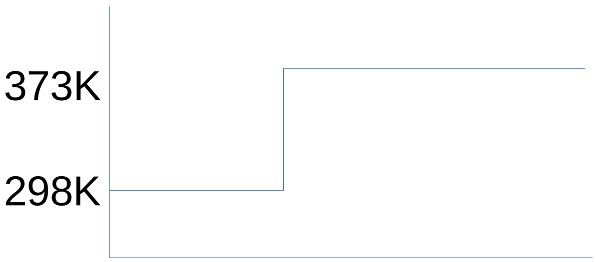
b) What is the relation between tensile force and resistance?

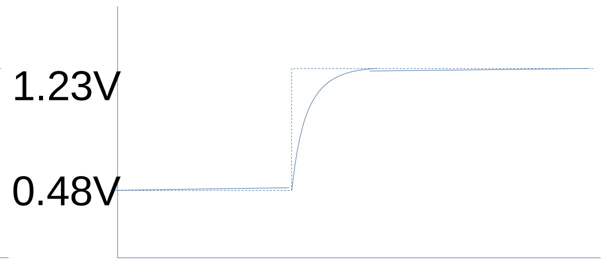
**<u>Solution</u>**

1. The step response of the system is of the form: $V_s(t)=A(1-e^{t/\tau})$

where A is the amplitude of the applied step. $A=V_{100^o C}-V_{25^o C}=0.01(100-25)=0.75$

$V(t)=0.48+0.75(1-e^{-t/\tau})$



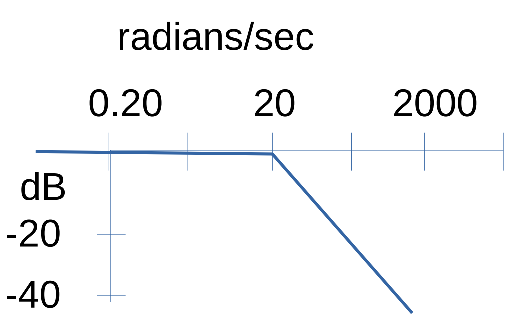

At $t$=0.02, $V(t$=0.02)=0.734. Substituting: $\frac{0.254}{0.75}=1-e^{-0.02/\tau}$ , $\ln(0.66)=\frac{-0.02}{\tau}$ , $\tau\approx 0.05$

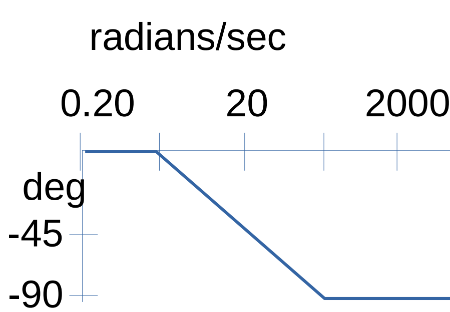
Time constant = 0.05s

$$H(s)=\frac{Gain}{1+\tau s}=\frac{0.01}{1+0.05s}, H(j\omega)=0.01\left[\frac{1}{1+\omega^2/400}-j\frac{\omega/20}{1+\omega^2/400}\right]$$

$$|H(s)|=\frac{1}{1+\omega^2/400} \quad , \quad phase=\tan^{-1}(-\omega/20)$$

| f | ω | Magnitude | dB | Phase (degrees) |
|---|---|---|---|---|
| 0.0318 | **0.2** | 1 | **0** | **0** |
| 0.318 | **2** | 0.99 | **0** | **-5.7** |
| 3.18 | **20** | 0.5 | **-3** | **-45** |
| 31.8 | **200** | 0.0099 | **-20** | **-84.3** |
| | | | | **-90** |



2. Resistance with zero tension: $R=\rho\frac{l}{\pi r^2}=400\,x\,10^{-6}\frac{0.1}{1\,x\,10^{-6}}=40\,\Omega$ => $\frac{l}{r^2}=0.314\,x\,10^{-6}$

New resistance with applied tension= 40.8

=> $\frac{(l+\Delta l)}{(r-\Delta r)^2}=0.320\,x\,10^6=\frac{l(1+\Delta l/l)}{r^2(1-\Delta r/r)^2}=\frac{l(1+\Delta l/l)}{r^2(1-\sigma\Delta l/l)^2}$ , $\sigma=0.3$

$\frac{(1+\Delta l/l)}{(1-0.3\,\Delta l/l)^2}=1.019$ , $\Delta l/l\approx 0.02$

Stress => $\phi=Y(\Delta l/l)=0.02\,x\,10^9$

a) Force => $F=\phi(\pi r^2)=0.02\,x\,10^9\,x\,1\,x\,10^{-6}=20\,N$

b) 20N force gives a 0.8 Ω change in resistance. Therefore, 25N / Ω.