CHEM 133 Exam 1
Mar. 7, 2017
KEY

Equations and constants that you may find useful:
Equation for voltage across resistor in RC circuit as a function of time for a step change of ΔV_{in} at time t = 0:

$V_R = \Delta V_{in} e^{-t/RC}$

Standard deviation:

$$S = \sqrt{\frac{\sum(x_i - \bar{x})^2}{n-1}}$$

Digitization equation for n bit digitizer: decimal # = $(V_{meas} - V_{min}) \cdot 2^n / V_{range}$

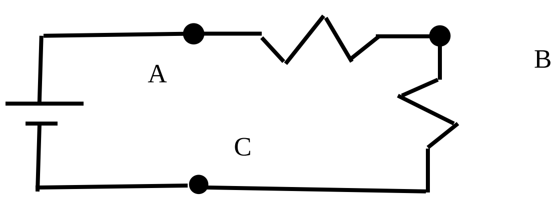
Noise Equations: 1) Thermal noise: $V_{noise}(rms) = (4kTRB)^{1/2}$
2) Shot Noise: $I_{noise}(rms) = (2eIB)^{1/2}$
k = Boltzmann's constant = 1.38 x 10^{-23} V^2 s Ω^{-1} K^{-1}, T = temperature (K), R = resistance, B = bandwidth, I = current, and e = elementary charge = 1.60 x 10^{-19} C. C = coulombs
F = Faraday's constant = 96,500 C/mol e
Nernst Equation:

$$E = E^o - \frac{RT}{nF}\ln Q = E^o - \frac{2.303RT}{nF}\log Q = E^o - \frac{0.05916}{n}\log Q \text{ (T = 298 K)}$$

R = Universal Gas Constant = 8.314 J mol^{-1} K^{-1}; n = moles e^-
Units: 1 A = 1 C/s; 1 J = 1 C·V; 1 W = 1 V·A , A = amps, V = volts, W = watts, J = joules

SHORT ANSWER SECTION: (Each question worth 4 points)

1. Adding a resistor where will cause an increase in current from the power supply?



a) inserted at point A
b) inserted at point B
c) connected between points A and C
d) any addition of a resistor will decrease current

2. A fluoride selective electrode has a useful output range of 0.6 to 2.1 V and is being recorded by a digitizer with an input voltage range of 0 to 1 V. Noise is not a major issue. What type of analog signal processing is needed?
a) RC high pass filter b) RC low pass filter **c) a voltage divider** d) a voltage amplifier

3. List a transducer for temperature measurement and the electrical output signal (e.g. voltage, current or resistance). Transducer _a) thermistor, b) PRT, c) thermocouple_ Output signal a/b) R, c) V__

4. A 10 bit analog to digital convertor allows input voltages from -500 mV to +500 mV. What is the average error in the signal read (in mV) following digitization?

a) 0.24 mV b) 0.49 mV c) 50 mV d) 100 mV

ave error = ½(smallest bit) = (1/2)[500 mV – (-500 mV)]($1/2^{10}$)

5. What type of noise is associated with slow drifts in signal response and can be reduced by modulating part of an instrument (to perform measurements at higher frequency)?

a) 1/f noise b) shot noise c) thermal noise d) Johnson noise

6. Which of the following quantities is most important in determining the amount of charge available from a battery:

a) E° values for the reaction b) Q, the reaction quotient

c) the moles of the limiting reagent d) Zeta, the kinematic supply coefficient

7. In an electrolytic cell,

a) chemical potential is used to perform electrical work

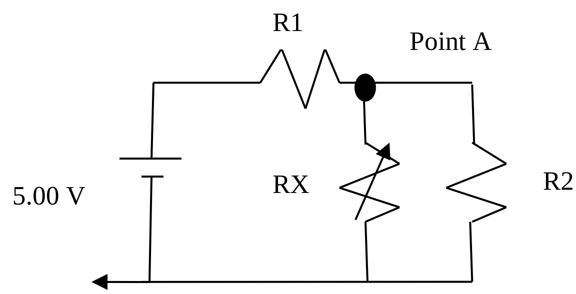
b) reduction occurs at the anode

c) a reference electrode is required

d) an external potential is used to carry out unfavorable reactions

SECTION II. PROBLEM SECTION. Show work – use the back side if needed

1. In the circuit to the right, if R1 = 220. Ω and R2 = 370. Ω, and V_A is measured as 2.31 V, calculate the following:



a) The current output at the power supply (6 pts)

I(power supply) = I_{R1}

= V_{R1}/I_{R1} = (5.00 V – 2.31 V)/220 Ω

I(power supply) = ***0.0122 A***

b) The current across resistor RX (6 pts)

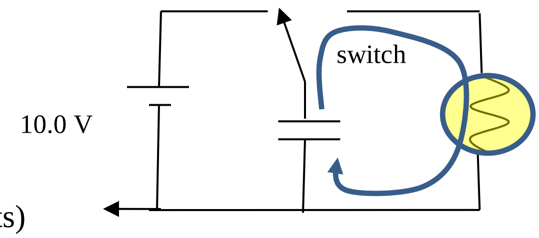
$I_{R1} = I_{R2} + I_{RX}$ or $I_{RX} = I_{R1} - I_{R2}$ and $I_{R2} = V_A/R2 = 2.31\ V/370\ \Omega = 0.00624\ A$

I_{RX} = 0.0122 A – 0.00624 A = ***0.0060 A***

c) The resistance of RX. (4 pts)

$RX = V_A/I_{RX}$ = 2.31 V/ 0.0060 A = 390 Ω

2. A capacitor (C = 50.0 μF) is charged in the circuit to the right and then discharged through a light that can be treated as a resistor (R = 40.0 Ω). If the capacitor is charged to 10.0 V and light will be emitted until the voltage drops to 3.0 V, how long will the light be on for after flipping the switch? (8 pts)
Note: switch will move from left side to right side to start capacitor discharge.

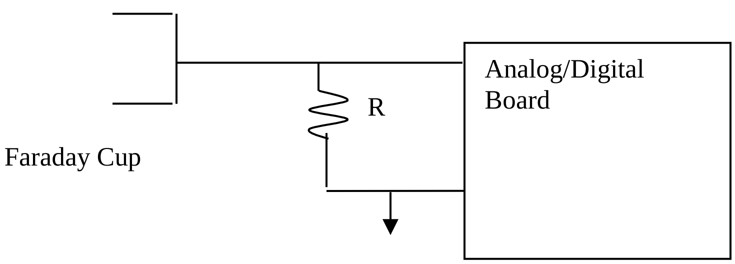


After flipping switch, 10 V in charged capacitor gets dissipated as it goes through the lamp as shown in the loop above. From Kirchhoff's potential law, we can write,

$V_C = V_R = (10.0V)e^{-t/RC} = 3.0V$ *or* $0.30 = e^{-t/RC}$ *or* $\ln(0.30) = -t/RC$

$t = -\ln(0.30)(40.0\ \Omega)(50.0 \times 10^{-6}\ F) = \mathbf{0.0024\ s}$

3. In the circuit shown below, a Faraday cup in a flame ionization detector (FID) is used to measure the current positive ions produce in the flame as they hit the cup. The A/D board records the voltage drop across the resistor with resistance = 135,000 Ω so that the Faraday cup current can be calculated. The FID current is proportional to flux (nmol C reaching the FID per second). The A/D board has 10 bits with a range of 0.000 to 0.500 V.
Answer the following questions below:



When 5.0 nmol C/s reaches the FID, the average binary number recorded by the A/D board is: 0101001110.

a) What is the corresponding decimal number? (5 pts)
we can get the decimal number by writing the 2 sequence and cancelling out any with 0s.

~~512~~ + 256 + ~~128~~ + 64 + ~~32 + 16~~ + 8 + 4 + 2 + ~~1~~ = ***334***

b) What voltage corresponds to A/D reading? (6 pts)

decimal # = $(V_{meas} - V_{min})\cdot 2^n/V_{range}$ *(see front page)*

$334 = (V - 0)(1024)/0.500\ V$

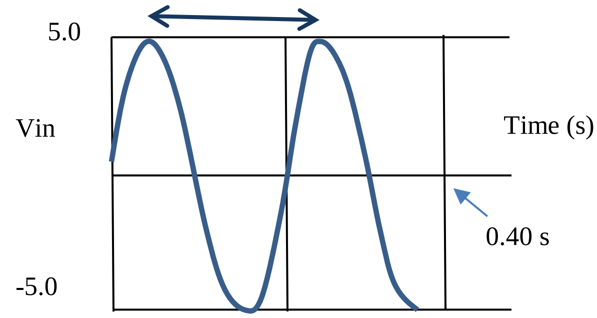
Or $V = (334)(0.500\ V)/1024 = \mathbf{0.163\ V}$

c) What is the current coming from the Faraday cup? (assume zero current through A/D board) (5 pts)

$I = V/R = 0.163\ V/(135{,}000\ \Omega) = 1.21 \times 10^{-6}\ A = 1.21\ \mu A$

3 – cont. – Bonus) Give the maximum detectable flux (in nmol/s). (3 pts)
Flux is proportional to current and to voltage so $F_{max}/F = V_{max}/V$
or $F_{max}/(5.0 \text{ nmol/s}) = (0.500 \text{ V}/0.163 \text{ V})$ *or* $F_{max} = (5.0 \text{ nmol/s})(3.07) =$ ***15 nmol/s***

4. Given the circuit and V vs. time plot to the right answer the following questions. (8 pts)



a) What is the frequency of V_{in}?

f = 1/(time period) (see arrow on plot)
f = 1/0.2 s = ***5 Hz***

b) If the plot above represents a perfect sine wave and extends infinitely along the time axes, describe what a Fourier transform of it would look like.
If a sine wave, a single line at 5 Hz would show up.

5. A compound is being analyzed by mass spectrometry and may have one or two sulfurs. Having one sulfur gives rise to an M + 2 isotope peak (from having an ^{34}S in place of a ^{32}S) about 4.5% as large as the M peak. When data is averaged for 50 scans, the signal to noise ratio for the M peak is 25. How many scans should the mass spectrometer run so that the signal to noise ratio in the M + 2 peak is 5 assuming 1 S present? (12 pts)
For M peak, S/N = 25. For M + 2 peak, signal is 4.5% as large so S/N = (0.045)(25) = 1.125
The desired S/N (for M + 2 peak) is 5 and the S/N is proportional to $n^{0.5}$
Or $(S/N)_n/(S/N)_{n=50} = (n/50)^{0.5}$ *or* $5/1.125 = (n/50)^{0.5}$ *or* $(5/1.125)^2 = n/50$
n = (19.8)(50) = 988 = ***990*** *(2 sig fig)*

6. A chemist is testing an electrode for measuring Cd^{2+} in solution by using the following cell: $Cd(s)|Cd^{2+}(aq, 0.0051\ M)||KCl(aq, 1.0\ M)|AgCl(s)|Ag(s)$. Given the E° for the following reactions, calculate the cell potential (remember in the cell notation that the left half is for oxidation). (12 pts)

Standard reduction potentials: $Cd^{2+}(aq) + 2e^- \leftrightarrow Cd(s)$ E° = -0.380 V
$AgCl(s) + e^- \leftrightarrow Ag(s) + Cl^-(aq)$ E° = 0.222 V

$E_{cell} = E_{cathode} – E_{anode}$ *and* $E_{cathode} = E° - (0.05916/1)\log[Cl^-] = 0.222 \text{ V} - 0$
$E_{anode} = E° - (0.05916/2)\log 1/[Cd^{2+}]$
$E_{cell} = 0.222 \text{ V} – [-0.380 \text{ V} - (0.05916/2)\log(1/0.0051)] = 0.602 + 0.068 =$ ***0.670 V***