BEGN 186B Winter 2012

Quiz 3

March 7, 2012

NAME (Last, First):

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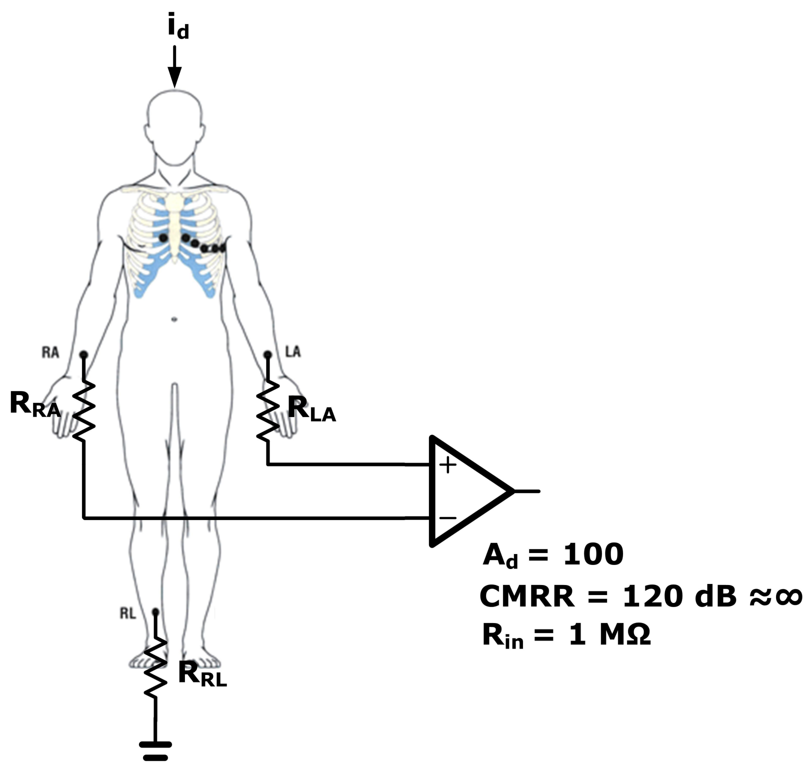
- This quiz is closed book and closed note. You may use a calculator for algebra.
- Circle your final answers in the space provided; show your work only on the pages provided.
- Do not attach separate sheets. If you need more space, use the back of the pages.
- Points for each problem are given in [brackets], 100 points total. The quiz is 50 minutes long.

1	/35
2	/20
3	/20
4	/25
Total	/100

1. [**35 pts**] Consider a bioinstrumentation amplifier with a differential gain $A_d = 100$, a practically infinite CMRR of 120 dB, and input impedance $R_{in} = 1\ M\Omega$. We want to connect the amplifier to measure an ECG signal using three electrodes RA, LA and LR in contact with the body. The electrode contact impedances are $R_{RA} = 110\ k\Omega$, $R_{LA} = 90\ k\Omega$ and $R_{RL} = 100\ k\Omega$.



   a. [15 pts] Find the differential gain A_{d1}, common-mode gain A_{c1} and $CMRR_1$ of the overall system with the bioinstrumentation amplifier connected to the RA and LA electrodes on the body.

   Answer: A_{d1} = ___________ $CMRR_1$ = ___________

   A_{c1} = ___________

b. [10 pts] Assume a displacement current of amplitude $i_d = 1\ \mu A$ from 60 Hz line noise entering the body. The RL electrode is connected to ground. Find the amplitude of the resulting 60 Hz common-mode voltage v_{cm} in the body and the corresponding common-mode voltage $v_{cm,out}$ at the amplifier output.

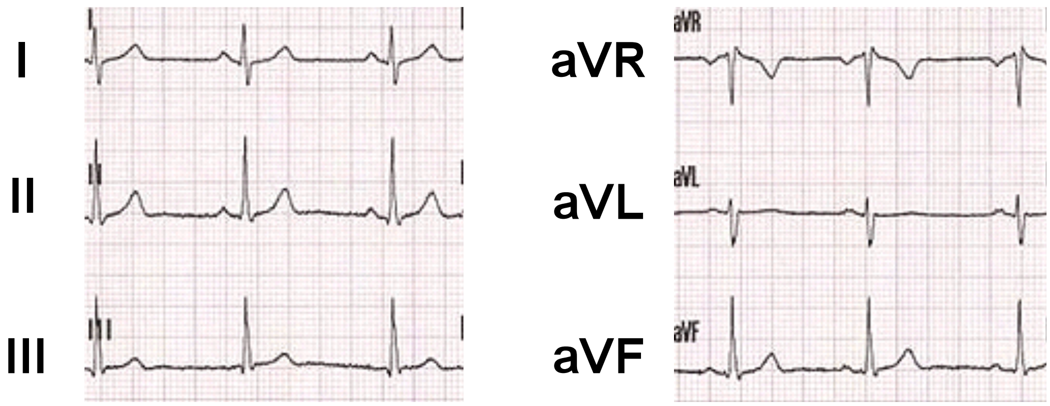
Answer: v_{cm} = __________

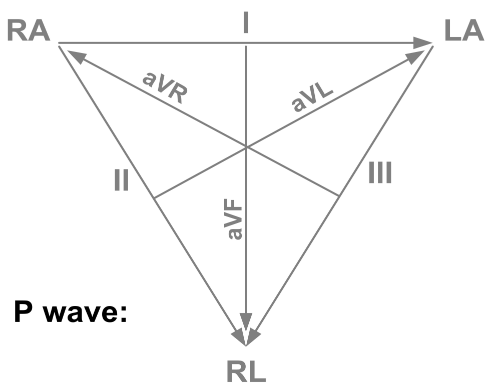
$v_{cm,out}$ = __________

c. [10 pts] Now the RL electrode is disconnected from ground, and a second amplifier is inserted to reduce the common-mode voltage using the driven right leg technique. The inputs of the second amplifier are connected to the LA and RA electrodes, and its output drives the RL electrode. Find the required common-mode gain A_{c2} of this amplifier such that v_{cm} in the body is reduced to 100 μV in amplitude.

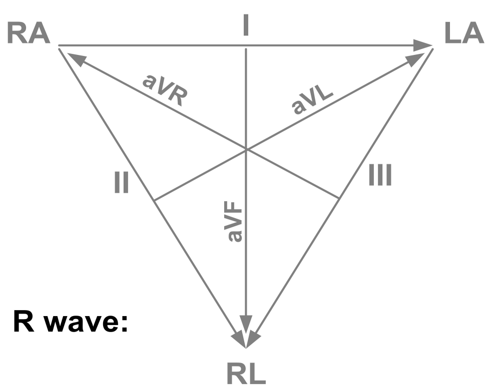
Answer: A_{c2} = _____________

2. [**20 pts**] Estimate, and sketch on the Einthoven's triangles below, the direction and relative magnitude of the cardiac vectors M at the ECG P, R and T waves. Show your reasoning. Hint: Try to look for leads that are approximately parallel and orthogonal to the cardiac vector.

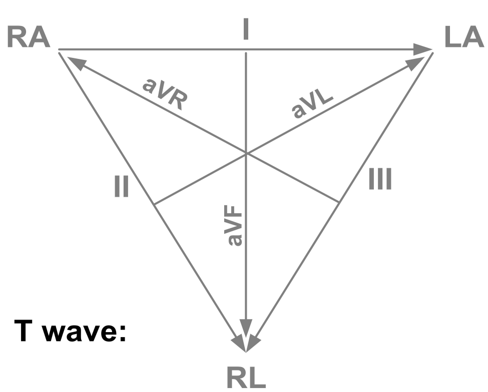




P wave:



R wave:



T wave:

3. [**20 pts**] Circle the best answer (circle only one letter for each question).

   a. **One advantage of using intravascular pressure monitoring instruments as opposed to external methods is:**
      i. Cheaper costs, reusability
      ii. Less invasive
      iii. Less affected by blood viscosity
      iv. Better frequency response
      v. Easy to sterilize

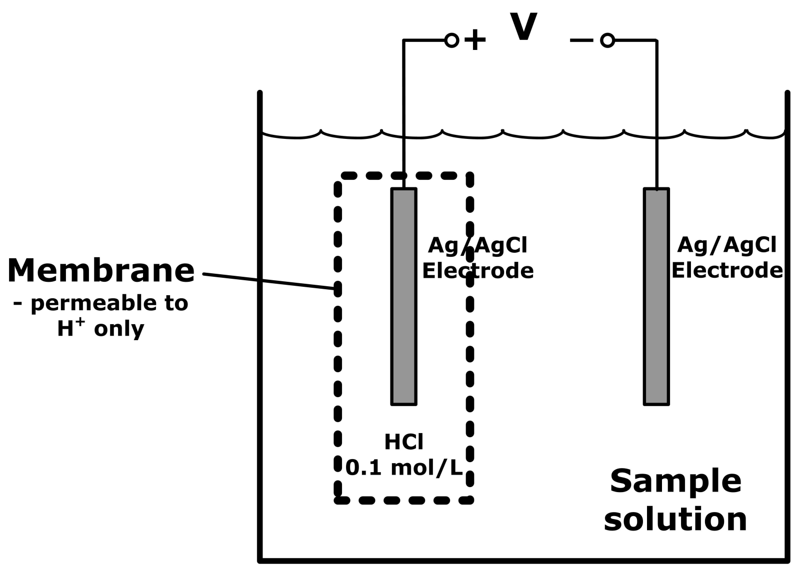
   b. **The following is NOT modeled as a capacitance in a hydraulic system's electrical analog:**
      i. The presence of bubbles in the catheter
      ii. The compressibility of the fluid
      iii. The viscosity of the fluid
      iv. The elasticity of the catheter
      v. The compliance of the diaphragm

   c. **Tonometry:**
      i. Uses sonic tones of different frequencies to measure flow velocity
      ii. Images by reconstructing from sections generated by a penetrating wave
      iii. Is a direct way to measure pressure
      iv. Measures deformation at the interface
      v. Requires an injection of a contrast agent or thermal solution

   d. **Electromagnetic flow sensors work by the following physical principle:**
      i. Electrical induction
      ii. Electrical capacitance
      iii. Coriolis force
      iv. Fick's law
      v. No-slip boundary condition

   e. **The Doppler frequency shift in ultrasonic velocity measurement is NOT directly proportional to:**
      i. Angle cosines between sound velocity and flow velocity
      ii. Speed of sound
      iii. Speed of the fluid
      iv. Emitted frequency
      v. Any of the above

4. [**25 pts**] A membrane separates a container into two compartments as shown below. The inside compartment contains a solution of 0.1 mol/L HCl, and a sample solution is contained in the outside compartment. Two identical Ag/AgCl electrodes are immersed, one in each compartment. The membrane between the compartments is permeable to H^+ ion only.



The Nernst potential equation for ion A^n where n is valance of the ion:

$$E = \frac{60mV}{n} \cdot \log_{10} \frac{\left[A^n\right]_o}{\left[A^n\right]_i}$$

a. [10 pts] Derive an expression for V as a function of the pH of the sample solution.

Answer: V = ______________________

b. [5 pts] Find the value of V for a sample of 0.01 mmol/L KOH in pure water.

Answer: V = _______________

c. [10 pts] Now find V after adding 0.01 mmol/L H_2SO_4 to the KOH solution in b.

Answer: V = _______________