BME 301

- There are 5 questions to be answered.
- There is a 6^{th} question for extra credit.
- Write neatly and clearly.

Exam 1

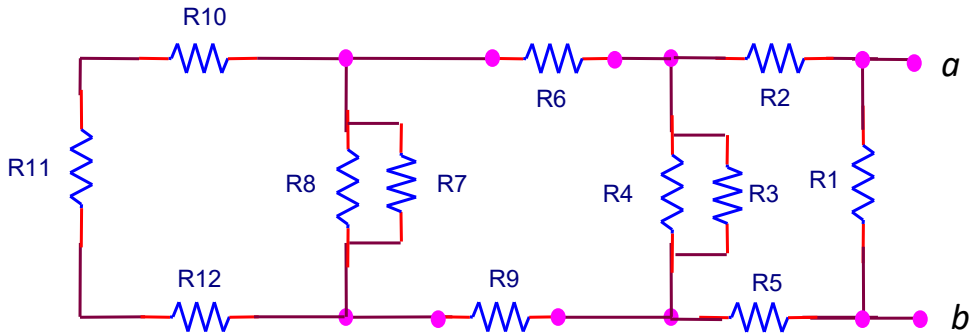
1. Action Potential
   a) Simply describe action potential in terms of electrical activity.
   b) What initiates Action Potential?
   c) Describe the 3 main states in terms of electrical activity that occurs for an action potential to be generated.
   d) What affects does Action Potential have on **muscles** and on **nerves**.
   e) Sketch the Action Potential, show where the electrical states occur, and what happens to **muscles** during these states.
2. ECG
   a) How are heart rhythms and blood flow related to action potential? What initiates this?
   b) Discuss the key phases of the heart and how action potential causes these phases to occur.

Exam 1

3. Electrical Basics
   a) Describe the electrical parameters that are required to create a working electrical system.
   b) Describe the rules for these electrical parameters adhere to.
   c) What are the key electrical circuit **elements** and describe how they function in a circuit. How many of these elements are needed for an electrical circuit to operate.
   d) How must these these elements be connected to support an electrical circuit? What must not be the connection method?

Exam 1

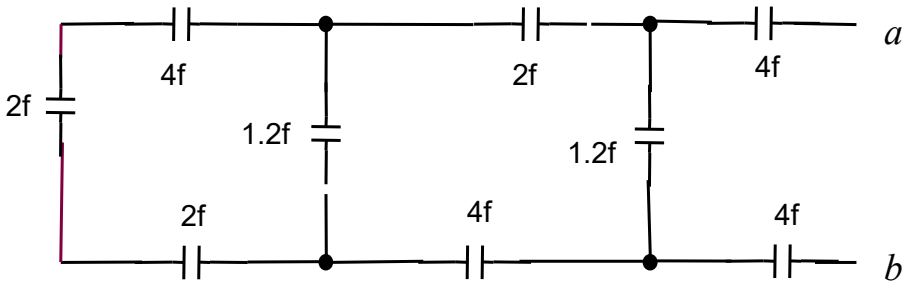
4. Simple Circuitry
   a) In the circuit in part b) what elements are in series and what elements are in parallel with respect to terminals a and b.
   b) Calculate the resistance of the following circuit with respect to terminals a-b where R1=10 ohms; R2=R5=4 ohms; R3=R4=6 ohms; R6=R9=2; R7=R8=6 ohms and R11=R12=R10=2 ohms.



Exam 1

4. Simple Circuitry

c) Determine the capacitance of the following circuit with respect to terminals a-b.

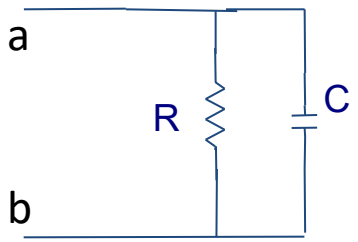


Exam 1

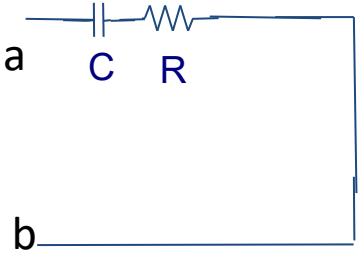
5. Complex circuits

   Find the impedance in the simplest polar form of the following circuits with respect to terminals a-b.

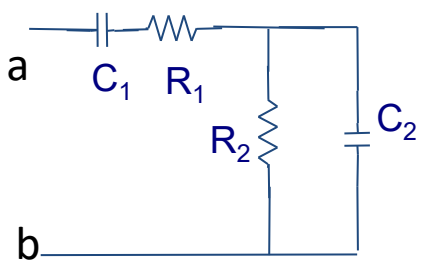
a)



b)



c)



Exam 1

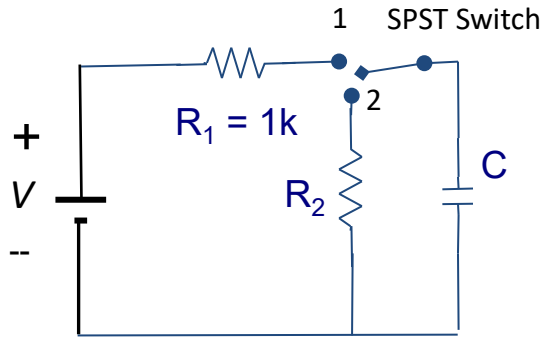
6. Extra Credit

a) Describe what happens when the switch is in position 1

b) Describe what happens when the switch is in position 2

c) The switch is in position 1 for 10msec and it is determined that the voltage across the capacitor reaches approximately 63% of its final value. What is the value of the capacitor?

d) The switch is moved to position 2. What should the value of R2 be for the capacitor to discharge its voltage 1000 times slower than when it charges?



Exam 1 Answers

1. Action Potential

   a) Simply describe action potential in terms of electrical activity.

   A change in voltage across a Cell membrane.

   b) What initiates Action Potential?

   A stimulating voltage such as the action potential of an adjunct cell.

   c) Describe the 3 main states in terms of electrical activity that occurs for an action potential to be generated.

   Rest state where the voltage across the membrane measured from outside of the cell to the inside of the cell is around -70mv.

   Depolarization where the voltage across the cell membrane rises to +30mv due to Na ions flowing into the cell.

   Repolarization where the voltage across the cell membrane returns to the Rest State by lowering the voltage across the membrane to -70mv due to K ions flowing out of the cell.

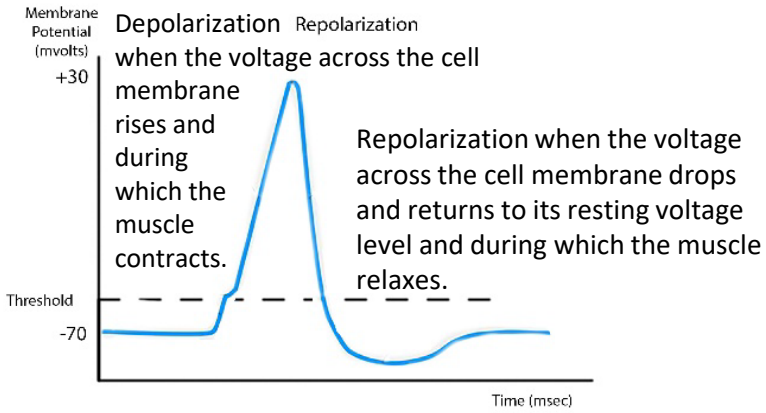
   d) What affects does Action Potential have on **muscles** and on **nerves**.

   For muscles, a contraction of the muscle occurs during Depolarization, and a relaxation of the muscle occurs during Repolarization. For nerve cells, AP causes an electrical signal to be transmitted down the axon.

Exam 1 Answers

1. Action Potential

   e) Sketch the Action Potential, show where the electrical states occur, and what happens to **muscles** during these states.



Exam 1 Answers

2. ECG

   a) How are heart rhythms and blood flow related to action potential? What initiates these phases?

The Action Potential causes the chambers to contract and relax causing oxygenated blood to flow into the body and deoxygenated blood to flow into the lungs to receive oxygen.

First the <u>Sinoatrial (SA)</u> node initiates the atria to contract and also sends a signal to the AV node to cause the ventricles to contract. IT then sends a delayed signal to <u>Atrioventricular (AV)</u> node which causes an Action Potential at the muscles of the ventricles to contract (the stimulus to depolarize).

Exam 1 Answers

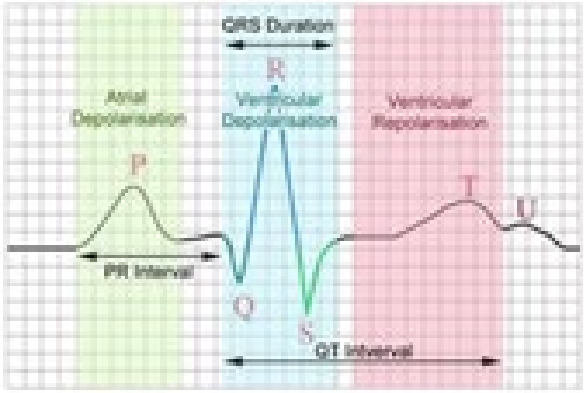
2. ECG

b) Discuss the key phases of the heart and how action potential causes these phases to occur.

During the <u>P wave</u> the atria contract (during AP depolarization of the cells in the atria) sending blood to the ventricles. The right atrium receives deoxygenated blood and then sends it to the right ventricle. The left atrium receives oxygenated blood to ne be sent to the left ventricle.

During the <u>QRS complex</u> the right ventricle contracts (during AP <u>depolarization</u> of the cells in the ventricles) and sends deoxygenated blood to the lungs obtain oxygen. The left ventricle contracts (during AP <u>depolarization</u> of the cells in the ventricles) and sends oxygenated blood to the body. During this time the atrium relax (during AP <u>repolarization</u> of the cells in the atria) but since the signal from the ventricles is large the atrium <u>depolarization</u> signal is not visible.

During the <u>T wave</u>, the ventricles relax (during AP <u>repolarization</u> of the cells in the ventricles) .



Exam 1 Answers

3. Electrical Basics

   a) Describe the electrical parameters that are required to create a working electrical system.

   The key electrical parameters are <u>current</u>, the movement or flow of charges and <u>voltage</u>, the force needs to move these charges.

   b) Describe the rules for these electrical parameters adhere to.

   <u>Kirchhoff's voltage law</u> (sum of the voltages around a loop must be equal to zero) and <u>Kirchhoff's</u> current law (sum of the currents entering or leaving a node must be equal to zero) .

Exam 1 Answers

3. Electrical Basics

c) What are the key electrical circuit **elements** and describe how they function in a circuit. How many of these elements are needed for an electrical circuit to operate.

The 5 linear electrical circuit elements are grouped into active and passive elements.

The active elements are voltage sources and current sources which provides the energy/power to the passive elements.

The passive elements are the resistor which dissipates the energy into heat, the inductor which stores the energy as a magnetic field and the capacitor which stores the energy as an electric field.

There needs to be at least one active element and one passive element.

Exam 1 Answers

3. Electrical Basics

d) How must these these elements be connected to support an electrical circuit? What must not be the connection method?

The active and passive elements must be connected to allow for a closed path for current to flow from the active element, through the passive elements and return to active elements. This is called a <u>closed circuit</u>.

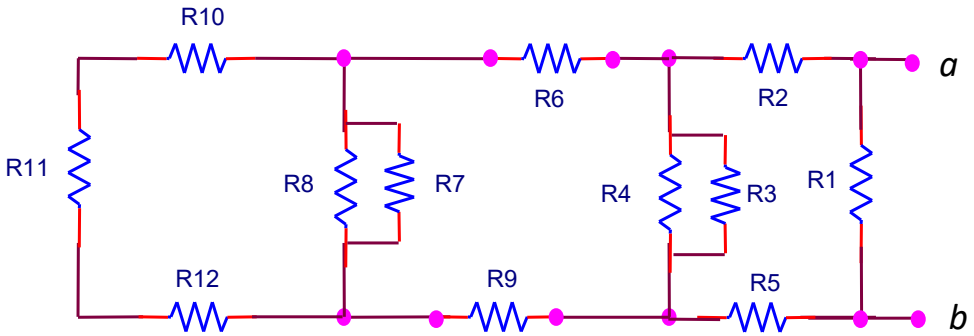
An <u>open circuit</u> where there is no closed path and can not support current flow.

Exam 1 Answers

4. Simple Circuitry

a) In the circuit in part b) what elements are in series and what elements are in parallel with respect to terminals a and b.

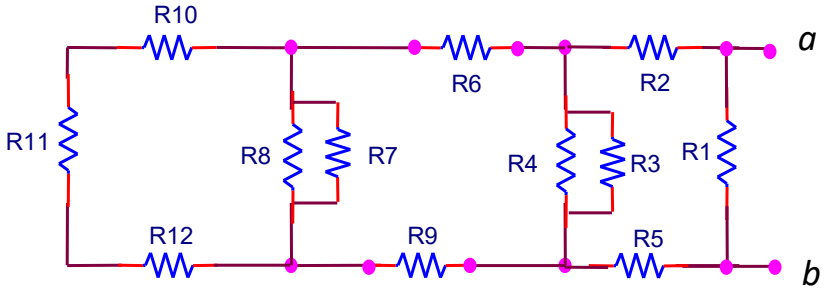
STEP 1: R10, R11, and R12 are all in series. Call this RA. STEP 2: RA is in parallel with R7 and R8. Call this RB. STEP 3: RB, R6 and R9 are in series; call this RC. STEP 4: RC is in parallel with R4 and R3. Call this RD. STEP 5: RD is in series with R3 and R5. Call this RE. Finally STEP 6: RE is in parallel with R1; call this RF. RF is Rab.



Exam 1 Answers

4. Simple Circuitry

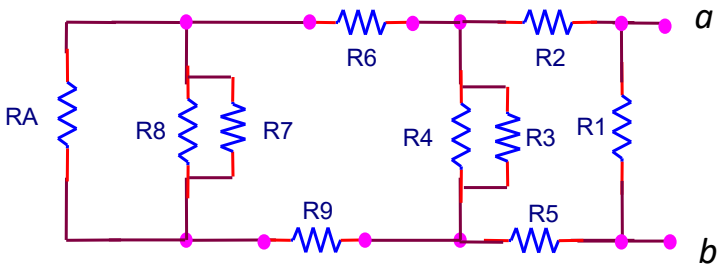
b) Calculate the resistance of the following circuit with respect to terminals a-b where R1=10 ohms; R2=R5=4 ohms; R3=R4=6 ohms , R6=R9=2; R7=R8=6 ohms and R11=R12=R10=2 ohms.



Step 1

RA=R10+R11+R12

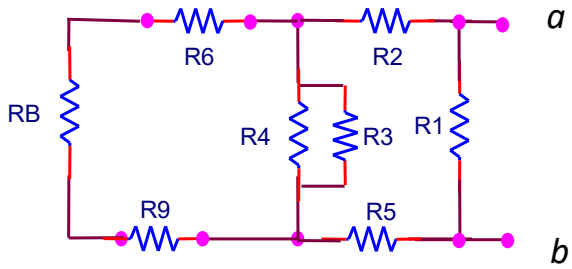
RA=2+2+2=6



Step 2

RB=RA||R7||R8

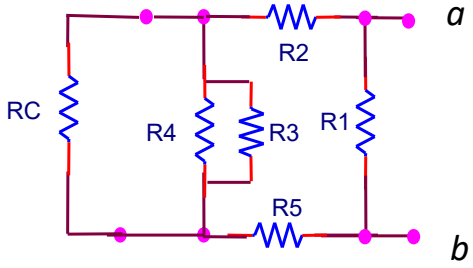
RB=6||6|| 6 = 2



Step 3

RC=RB+R6+R9

RC=2+2+2 = 6



Step 4

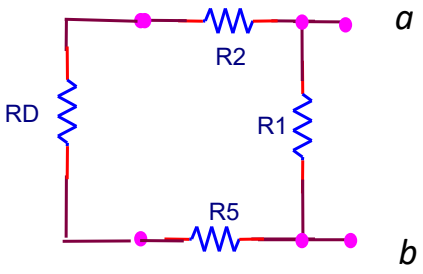
RD=RC||R4||R3

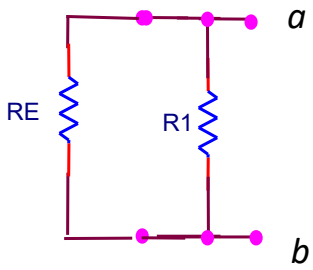
RD=6||6||6 = 2

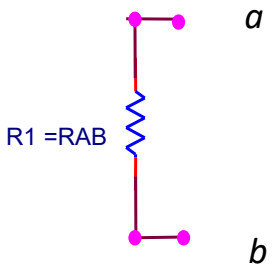
Exam 1 Answers

4. Simple Circuitry

b) Calculate the resistance of the following circuit with respect to terminals a-b where R1=10 ohms; R2=R5=4 ohms; R3=R4=6 ohms , R6=R9=2; R7=R8=6 ohms and R11=R12=R10=2 ohms.







Step 5

RE=RD+R5+R2

RE=2+4+4 = 10

Step 6

RF=RE||R1

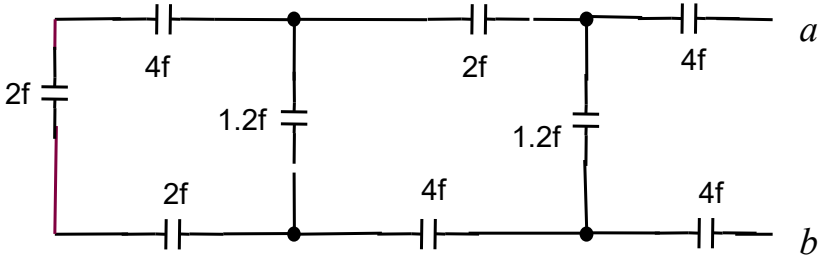
RF=10||10 = 5

RAB = RF = 5

Exam 1 Answers

4. Simple Circuitry

   c) Determine the capacitance of the following circuit with respect to terminals a-b.



$$CA = 4 \text{ in series } 2 \text{ in series } 2 = \frac{1}{\frac{1}{4}+\frac{1}{2}+\frac{1}{2}} = \frac{4}{5}$$

$$CB = CA \text{ in parallel with } \frac{6}{5} = CA \| \frac{6}{5} = \frac{4}{5} \| \frac{6}{5} = 2$$

$$CC = CB \text{ in series } 4 \text{ in series } 2 = \frac{1}{\frac{1}{4}+\frac{1}{2}+\frac{1}{2}} = \frac{4}{5}$$

$$CD = CC \text{ in parallel with } CC \| \frac{6}{5} = CA \| \frac{6}{5} = \frac{4}{5} \| \frac{6}{5} = 2$$

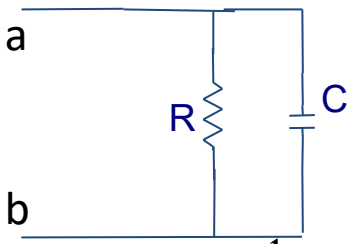
$$Cab = CD \text{ in series } 4 \text{ in series } 4 = \frac{1}{\frac{1}{2}+\frac{1}{4}+\frac{1}{4}} = 1$$

Exam 1 Answers

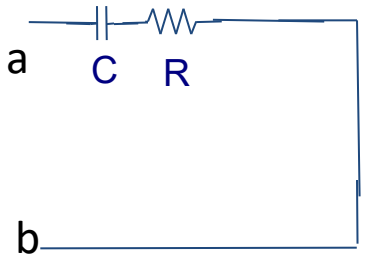
5. Complex circuits

Find the impedance in the simplest polar form of the following circuits with respect to terminals a-b

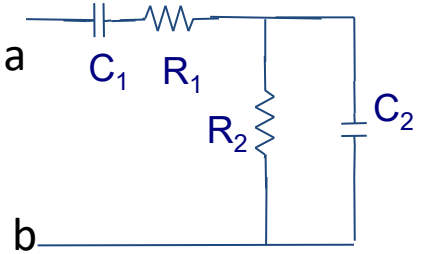
a)



b)



c)



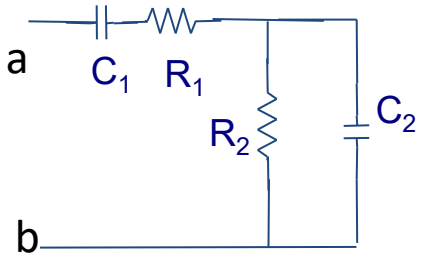
$$a)\ R \| \frac{1}{j\omega C} = \frac{R\frac{1}{j\omega C}}{R+\frac{1}{j\omega C}} = \frac{R}{1+j\omega RC} = \frac{R}{\sqrt{1+(\omega RC)^2}\angle \tan^{-1}(\omega 2RC)} = \frac{R}{\sqrt{1+(\omega RC)^2}} \angle -\tan^{-1}(\omega RC)$$

$$b)\ R+\frac{1}{j\omega C} = \frac{1+j\omega RC}{j\omega C} = \frac{\sqrt{1+(\omega RC)^2}\angle \tan^{-1}(\omega RC)}{\omega C \angle \frac{\pi}{2}} = \frac{\sqrt{1+(\omega RC)^2}}{\omega C} \angle [\tan^{-1}(\omega RC) - \frac{\pi}{2}]$$

Exam 1 Answers

5. Complex circuits

Find the impedance in the simplest polar form of the following circuits with respect to terminals a-b.



$$c)\ R_1+\frac{1}{j\omega C_1}+R_2\,\|\,\frac{1}{j\omega C_2}=\frac{1+j\omega R_1C_1}{j\omega C_1}+\frac{R_2}{1+j\omega R_2C_2}=\frac{(1+j\omega R_1C_1)(1+j\omega R_2C_2)+j\omega R_2C_1}{j\omega C_1(1+j\omega R_2C_2)}$$

$$=\frac{1-\omega^2R_1C_1R_2C_2+j\omega(R_2C_2+R_1C_1+R_2C_1)}{-\omega^2C_1R_2C_2+j\omega C_1}$$

$$=\frac{\sqrt{(1-\omega^2R_1C_1R_2C_2)^2+(\omega(R_2C_2+R_1C_1+R_2C_1))^2}\,\angle\tan^{-1}\left(\frac{\omega(R_2C_2+R_1C_1+R_2C_1)}{1-\omega^2R_1C_1R_2C_2}\right)}{\sqrt{(\omega^2C_1R_2C_2)^2+(\omega C_1)^2}\,\angle\tan^{-1}\left(\frac{\omega C_1}{-\omega^2C_1R_2C_2}\right)}$$

$$=\frac{\sqrt{(1-\omega^2R_1C_1R_2C_2)^2+(\omega(R_2C_2+R_1C_1+R_2C_1))^2}}{\sqrt{(\omega^2C_1R_2C_2)^2+(\omega C_1)^2}}\angle\tan^{-1}\left(\frac{\omega(R_2C_2+R_1C_1+R_2C_1)}{1-\omega^2R_1C_1R_2C_2}\right)-\angle\tan^{-1}\left(\frac{\omega C_1}{-\omega^2C_1R_2C_2}\right)$$

Exam 1 Answers

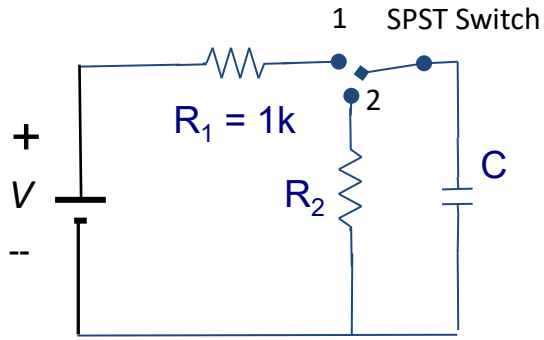
6. Extra Credit/Honors

a) Describe what happens when the switch is in position 1

The capacitor charges through R_1.

b) Describe what happens when the switch is in position 2

The capacitor discharges through R_2.



Exam 1 Answers

6. Extra Credit

c) The switch is in position 1 for 10msec and it is determined that the voltage across the capacitor reaches approximately 63% of its final value. What is the value of the capacitor?

The voltage for a charging capacitor is

$V_C(t) = V(1 - e^{-\frac{t}{RC}}) = V(1 - e^{-\frac{t}{\tau}})$ where τ is the time constant RC

And 63 percent is when $t_{63\%}$ is:

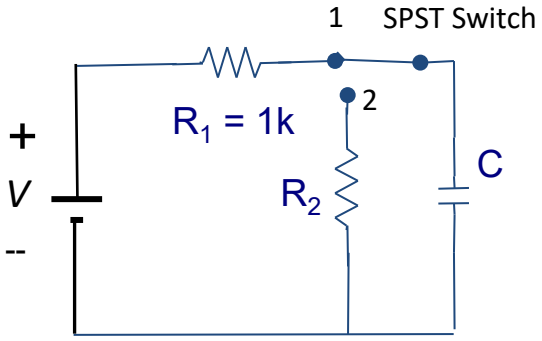
$$\frac{V(t_{63\%})}{V} = 0.63 = (1 - e^{-\frac{t_{63\%}}{\tau}})$$

$0.37 = e^{-\frac{t_{63\%}}{\tau}} \Rightarrow \ln 0.37 \cong -1 = -\frac{t_{63\%}}{\tau}$ Therefore 63% is one time constant.

$t_{63\%} = \tau$ or 1 time constant

$\therefore \tau = RC = 10\text{msec} = 0.010$

$$\therefore C = \frac{0.01}{1000} = 1 \times 10^{-5} = 10\mu f$$



Exam 1 Answers

6. Extra Credit/Honors

d) The switch is moved to position 2. What should the value of R2 be for the capacitor to discharge its voltage 1000 times slower than when it charges?

1000 times slower would make the time constant = $0.01 \times 1000 = 1 \times 10^{-2} \times 1 \times 10^{3} = 10\,\text{sec}$

$$\therefore R_2 C = 10 \Rightarrow R_2 = \frac{10}{1 \times 10^{-5}} = 10^{6} = 1M\Omega$$