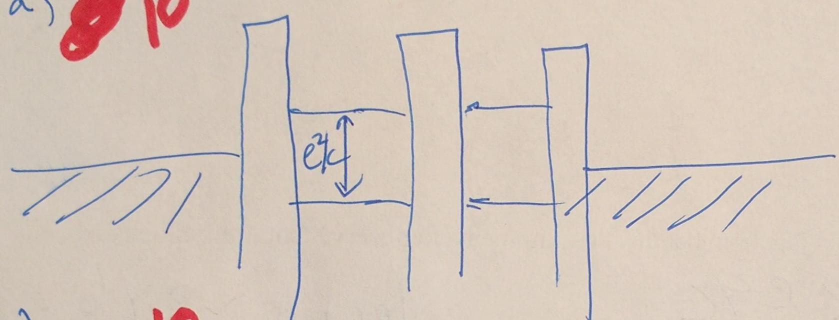
5. [50 pts] Coulomb blockade. Consider the two-island circuit with two gates. Draw the band diagram for small source-drain voltage at V_{g1}=, V_{g2}=0. Is current flowing under this condition? Next, draw the band diagram at several different times and the associated gate voltages (time dependent) in order to allow current to flow from source to drain at small source-drain bias voltage. How much current flows and how does this depend on the waveform of the gate voltages and the source drain bias voltage?

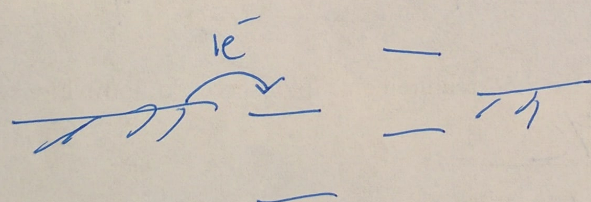
a) ~~8~~ 10



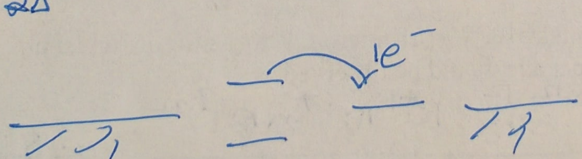
b) No 10

c) 5

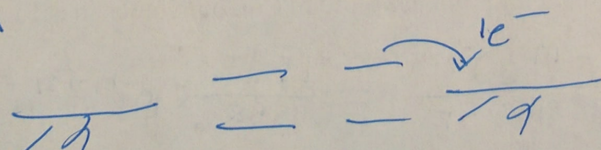
t = Δ



t = 2Δ



t = 3Δ



d) 10 $I = e \cdot F$

F = Frequency of waveform

e) ~~8~~ 10 As long as e can tunnel, waveform can be square, triangle, etc.

10 ~~f) independent~~

10 ~~g) independent~~

10 F) independent

EECS277C Winter 2017

2/23/2017 3:30 to 4:50 pm

Professor Peter Burke

Midterm #1 Name: Solutions

ID no.: ____________________

1	2	3	4	5	Total
/15	/10	/10	/10	/45	/100

45 55

Helpful constants for you:

$c = 3\ 10^{8}$ m/s
$e = 1.6\ 10^{-19}$ coulombs
$h = 6.63\ 10^{-34}$ J-s
$m = 9.1\ 10^{-31}$ kg
$k_B = 1.38\ 10^{-23}$ J/K
$h/e^2 = 25$ k□

1. [15 pts.] For a single tunnel junction, list the 3 requirements to observe Coulomb blockade:

Requirement # 1 $kT < e^2/C$ lect #5 P. 16

Requirement # 2 $R_T > h/e^2$

Requirement # 3 $Z(\omega) > R_T$ up to $\omega \sim \frac{1}{R_q C}$

2. [15 pts.] For a double tunnel junction, list the 2 requirements to observe Coulomb blockade:

Requirement # 1 $kT < e^2/C$

Requirement # 2 $R_T > h/e^2$

3. [10 pts] Consider a MOS capacitor with k=10, W=0.1 micron, L=0.1 micron, d=10 nm. What is the temperature at which Coulomb blockade would be observed?

$-12+1-7-7+8$

$$C = \frac{\epsilon A}{d} = \frac{8.85\times10^{-12}\frac{F}{m}\ 10^{+1}\ 10^{-7}m\ 10^{-7}m}{10^{-8}m} = 8.85\times10^{-17}\ F$$

4. [10 pts] What is the L and W required for room temperature Coulomb blockade effect to be observed for the case of problem #3?

$$\frac{e^2}{C} = \frac{(1.6\times10^{-19}\ C)^2}{8.85\times10^{-17}\ F} = \frac{1.6\times1.6}{8.85}\times10^{-19-19+17}\ J = 0.29\times10^{-21}\ J$$

$kT = 4.1\times10^{-21}$ J @ room temp. (300K) $\frac{kT}{e^2/C} = \frac{4.11}{0.29} = 14.1$ $T = \frac{300}{14.1}K = 21K$ (3)

(4) Need A 14x small $\Rightarrow$ L, W $\sqrt{14}$ smaller

$\Rightarrow$ 0.026 μm (4)

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