First letter of last name S

THE UNIVERSITY OF BRITISH COLUMBIA

Physics 158 (E&M) MT-1 Exam
February 10, 2015 Time: 60 min.

Student Number: 12345678 **Activity ID:** 007

Candidate's Name: STUDENT, SUSI Q
Last Name First Name

Signature: ____________________

Section Number (circle one):

201 MWF 9am 202 MWF 1pm 203 Tu/Th 2pm

This examination consists of 3 questions. Please check to ensure that this paper is complete. One page of formulae/constants will also be provided.

Show all relevant work and explain your reasoning. Unjustified answers will not receive any marks.
Please write using a **pen**.

Please read and observe the following rules:

(a) Each candidate should place his/her UBC card on their desk for identification.
(b) No candidate shall be permitted to enter the examination room after the expiration of one-half hour, or to leave during the first half-hour of the examination.

Caution: Candidates guilty of any of the following, or similar dishonest practices shall be immediately dismissed from the examination and shall be liable to disciplinary action:

(a) Making use of any books, memoranda, calculators, **Cell-Phones**, audio or visual players or other memory aid devices, other than those authorised by the examiners.
(b) Speaking or communicating with other candidates.

Each question is worth 10 marks.

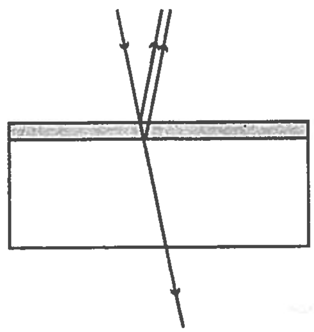
1 ____ / 10 2 ____ / 10 3 ____ / 10

Total ____ / 30

1. An optical filter is a device which preferentially transmits desired wavelengths of light while reflecting others. A simple optical filter can be constructed from a thin film of titanium dioxide ($n_f = 2.68$) deposited on optical glass ($n_g = 1.53$), as shown in the diagram. You may treat the layer of glass as being much thicker than the layer of TiO_2 and assume normal incidence for the light rays. The spectrum of visible light ranges from 390–700 nm.

(a) If three of the wavelengths of electromagnetic radiation maximally reflected by the filter are $\lambda_1 = 2070$ nm (infrared), $\lambda_2 = 690$ nm (red light), and $\lambda_3 = 414$ nm (violet light), what is the thickness of the thin film?

(b) What wavelength of visible light is preferentially transmitted by this optical filter? (Hint: if an incident wave is preferentially transmitted, what must be true of its reflected waves?) If you are unable to determine the actual film thickness in part (a) you can use $t = 250$nm. NOTE–THIS IS NOT THE CORRECT ANSWER.



2. Consider the circuit on the left with $R_1 = 1\ \Omega$, $R_2 = 2\ \Omega$, $R_3 = 3\ \Omega$, $C_2 = 2\mu$F, and $C_3 = 3\mu$F. Both capacitors are initially uncharged when the switch S_1 is closed at $t = 0$.

(a) Write an equation for the current, $i_1(t)$, passing through R_1 using the numerical values provided.

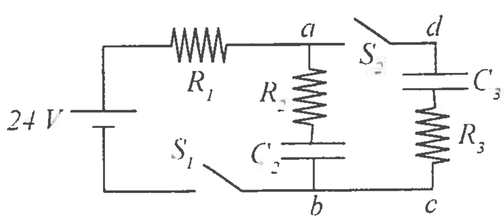
(b) What is the final charge on C_2, a long time after the switch S_1 is closed?

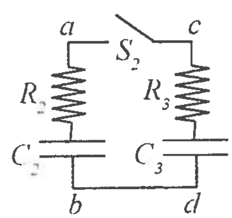
(c) Next we also close switch S_2. What are the final charges on the capacitors, Q_2 and Q_3, a long time after the switch S_2 is closed?

A Physics 158 student forgets to discharge these two capacitors before disconnecting them. The next day another P158 student reconnects them with reverse polarity as shown in the figure on the right.

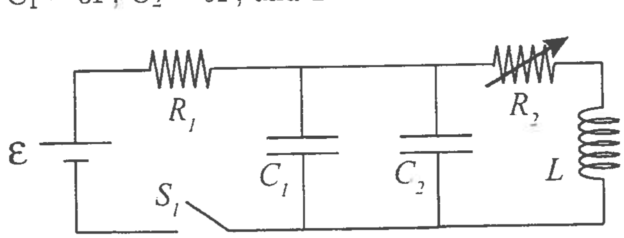
(d) Calculate $|V_{ab}|$ and $|V_{cd}|$ a long time after the switch S_2 is closed.

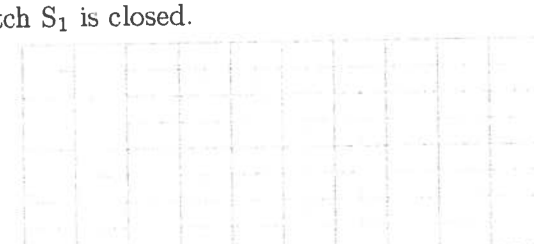
(e) How much charge flows through the switch S_2?





3. Consider the LRC circuit shown below. Use $\varepsilon = 10$V, $R_1 = 2\Omega$, R_2 is a variable resistor initially set to 5Ω, $C_1 = 3$F, $C_2 = 5$F, and $L = 10$H. At $t = 0$ the switch S_1 is closed.





(a) What is the voltage drop across the inductor L at $t = 0$?

(b) What is the current provided by the battery at $t = 0$?

(c) What is the charge on capacitor C_1 after a long time?

Now suppose that the variable resistance R_2 is reduced to zero. After waiting for the system to reach a new steady state, we open the switch S_1. We redefine this new time to be $t' = 0$.

(d) Sketch on the graph paper above the total charge $Q(t')$ on the top capacitor plates.

(e) What is the maximum energy stored in the capacitors?

(f) When does the **magnitude** of the capacitor charge first reach its maximum value?

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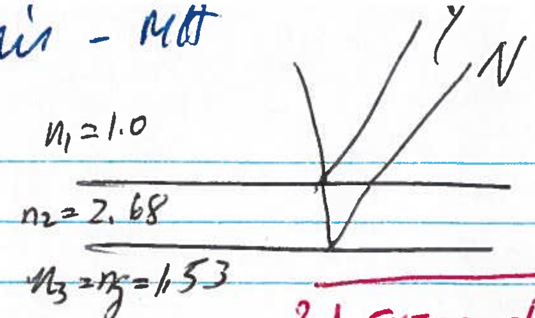


① $\lambda_1 = 2070\,nm$ (IR)

$\lambda_2 = 690\,nm$ (red)

$\lambda_3 = 414\,nm$ (violet)

For MAX refln $\quad 2t + \frac{\lambda}{2(2.68)} = m \frac{\lambda}{2.68}$

{ 1 EXTRA phase shift ⇒ integer λ ⇒ ½ integer λ

Use λ_1 $\quad 2t = (m_1 - \frac{1}{2}) \frac{2070}{2.68} = (m_1 - \frac{1}{2})\, 772\,nm$

$t_1 = (m_1 - \frac{1}{2})\, 386\,nm = \frac{1}{2}(386), \frac{3}{2}(386), \frac{5}{2}(386)\ nm$

$= 193\,nm, 579\,nm, 965\,nm$

Use λ_2 $\quad 2t_2 = (m_2 - \frac{1}{2}) \frac{690}{2.68} = (m_2 - \frac{1}{2})\, 257.5 =$

$t_2 = \frac{1}{2}(\frac{3}{2}$ or $\frac{5}{2})(128.7) = 64.4\,nm, 193\,nm, 322\,nm$

Use λ_3

$2t_3 = (m_3 - \frac{1}{2}) \frac{414}{2.68} = (m_3 - \frac{1}{2})(154.5) =$

$t_3 = (m_3 - \frac{1}{2})(77.2) = 38.6, 115.8, 193\,nm$

(b) Take minimum refln ⇒ MAX transmission

$$2t + \frac{\lambda}{2(2.68)} = (m - \tfrac{1}{2}) \frac{\lambda}{2.68} \qquad m = 1, 2, 3$$

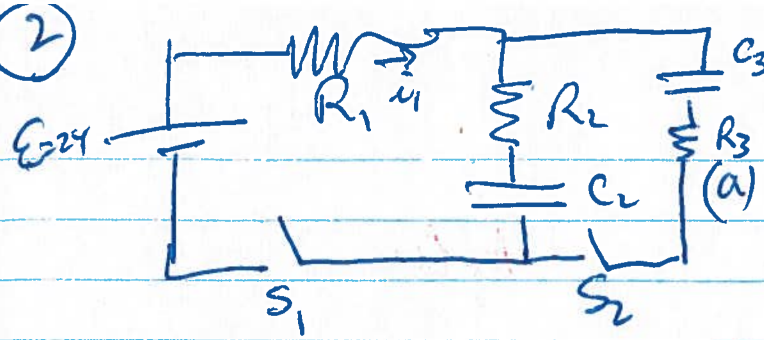
$$\therefore 2t' = m \frac{\lambda}{2.68}$$

for t' = 250nm,
/lambda = 670nm (m=2)
or 447nm (m=3)

$$\lambda_{TRANS} = \frac{2(2.68)(193\,nm)}{m}$$

$= 1034.5/m \Rightarrow$ **517 nm**

(2)



close S_1

(a) $i_1(t) = i_1(0)\, e^{-t/(R_1+R_2)C_2}$

$i_1(0) = 24/3\Omega = 8A$

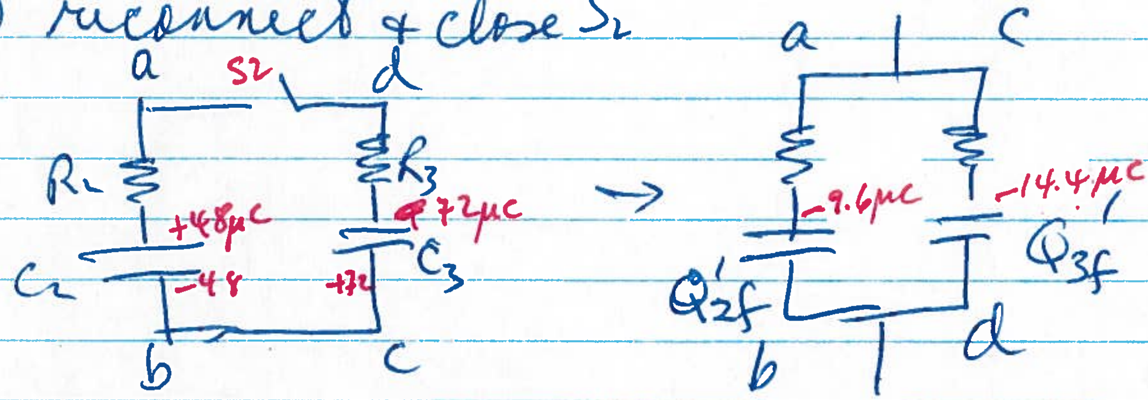
$i_1(t) = 8A\left[e^{-t/3(2)\mu sec}\right]$

$= 8\left(e^{-t/6(\mu sec)}\right)$

(b) $Q_2 = C_2 V_2 = 2\mu F(24) = 48\mu C$

(c) now close S_2 $Q_3 = C_3 V_3 = 3\mu F(24V) = 72\mu C$

now reconnect & close S_2



Q_{TOP} (before) $= +48 - 72 = -24\mu C = Q_2' + Q_3'$

$V_{ab} = \dfrac{Q_2'}{C_2} = V_{cd} = \dfrac{Q_3'}{C_3}$ $\qquad Q_3' = Q_2' \dfrac{C_3}{C_2}$

$\therefore\ Q_2' + Q_2'\left(\dfrac{C_3}{C_2}\right) = -24$

$Q_2' = \dfrac{-24}{1+3/2} = \dfrac{-24}{2.5} = -9.6\mu C$

$Q_3' = -9.6\left(\dfrac{3}{2}\right) = -14.4\mu C$

$\Delta Q = 48 + 9.6 = 57.6\mu C$

$V' = \dfrac{Q_2'}{C_2} = \dfrac{-9.6\mu C}{2\mu F} = -4.8$ Volts

3 (a) $\mathcal{E}_L = 0$ since C_1 & C_2 have no charge & therefore $V_{C_1} = V_{C_2} = 0$

(b) $i_b = i_{R_1}(0) = \frac{\mathcal{E}}{R_1} = \frac{10V}{2\Omega} = 5A.$

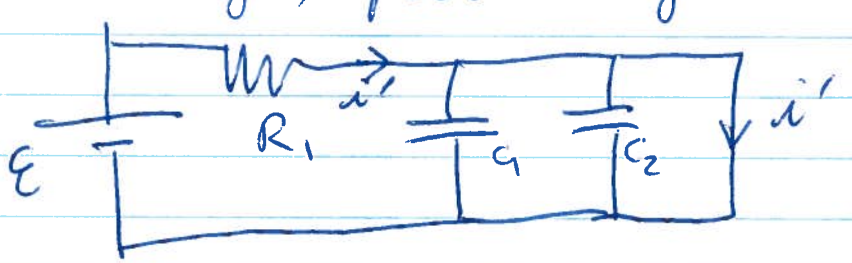
NOTE $i_{R_2} = i_L = 0$ at $t = 0$

(c) $Q_1(\infty) = C_1 V_1(\infty)$ $\quad V_1 = \frac{\mathcal{E}}{R_1 + R_2} R_2 = \frac{10}{7}(5) = 7.14V$

$\therefore Q_1 = 3(7.14) = 21.4\ C$

$Q_2 = 5 V_1 = 35.7\ C$

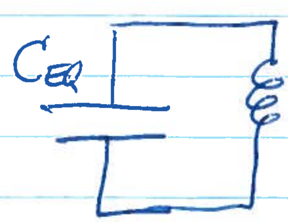
Now let $R_2 \to 0$ Then current will flow through the inductor (which becomes a WIRE — NO voltage) after a long time.



Hence $i' = \frac{\mathcal{E}}{R_1} = \frac{10}{2} = 5$ Amps

$V_{C_1}' = V_{C_2}' = 0$

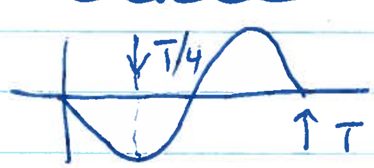
Now we open S_1



$\downarrow I_2(0) = 5A$

$C_{EQ} = C_1 + C_2 = 8F$

(d)



(e) $U_C = \frac{1}{2}\frac{Q_E^2}{C_E} = \frac{1}{2} C_E V_1^2 = \frac{1}{2} L\, I_2(0)^2 = \frac{1}{2}(10)(25) = 125\ J$

(f) $t_1 = T/4 = \frac{1}{4f}$, $\omega = 2\pi f = \frac{1}{\sqrt{LC}} \Rightarrow t_1 = \frac{\pi}{2}\sqrt{LC} = 14.0$ sec