PHYS 102: General Physics 2 **KOÇ UNIVERSITY** **Spring Semester 2011**

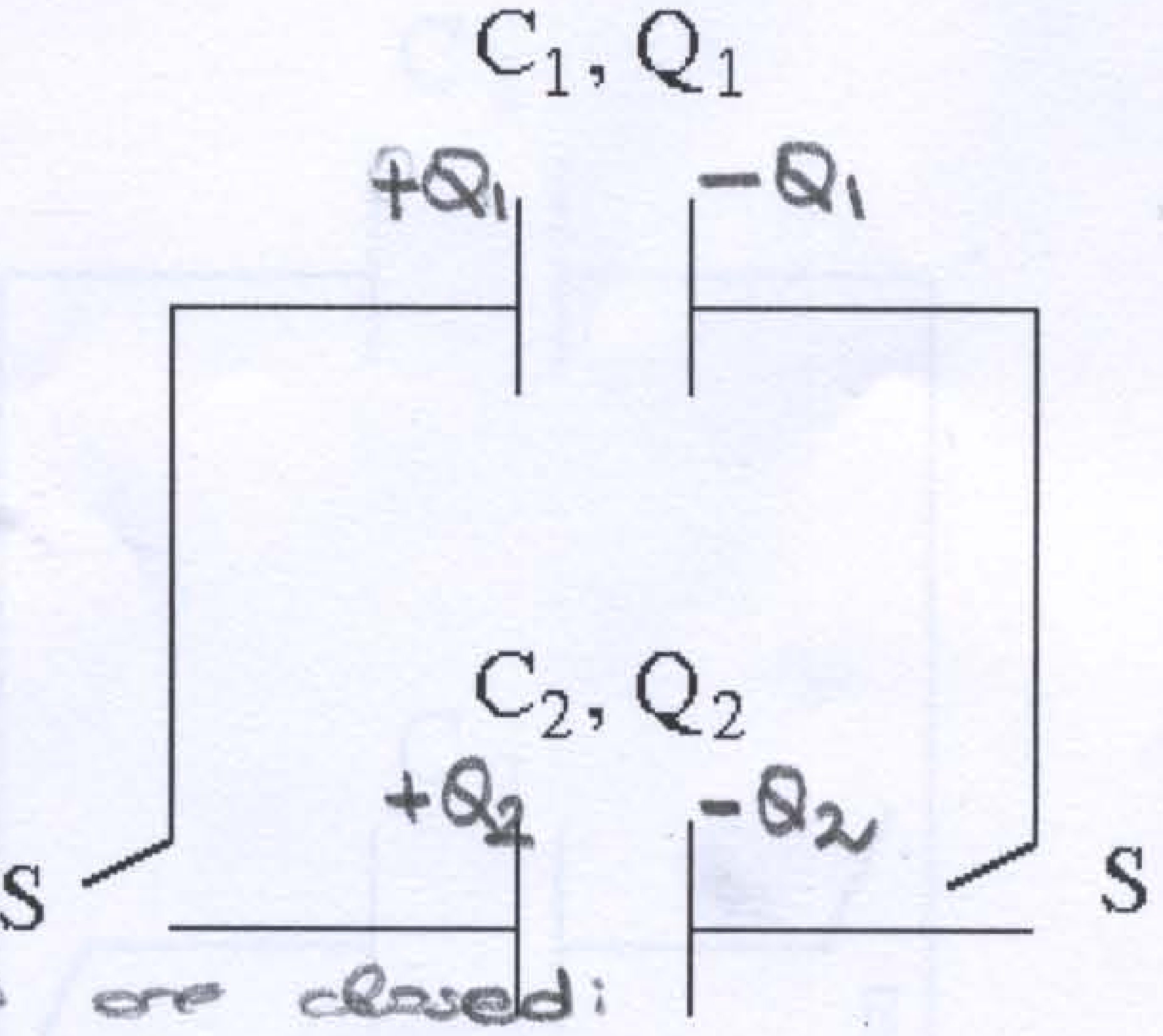
College of Sciences

Section 1 **Quiz 4** **10 March 2011**

Closed book. No calculators are to be used for this quiz.
Quiz duration: 10 minutes

Name: **Student ID:** **Signature:**

Initially the switches (labeled by S) are open, and both of the capacitors are charged as shown in the figure. After switched are closed, calculate the final energy stored in the second capacitor (C_2) in terms of the capacitances and initial charges.



When the switches are closed:

*Charge is conserved, $Q = Q_1 + Q_2$

*Potential difference for both capacitors is the same

⇒ Hence they are parallel connected!

$$C_{eq} = C_1 + C_2$$

* Each share the total charge Q wrt ratio of their capacitance's

$$\frac{Q_{1f}}{Q_{2f}} = \frac{C_1}{C_2} \quad \& \quad Q_{1f} + Q_{2f} = Q$$

$$\frac{C_1}{C_2} \cdot Q_{2f} + Q_{2f} = Q_1 + Q_2$$

$$Q_{2f}\left(\frac{C_1 + C_2}{C_2}\right) = Q_1 + Q_2$$

$$\Rightarrow \boxed{Q_{2f} = (Q_1 + Q_2) \cdot \frac{C_2}{C_1 + C_2}}$$

* Energy Stored,

$$U = \frac{Q^2}{2C}$$

$$U_{2f} = \frac{Q_{2f}^2}{2C_2} = \frac{(Q_1 + Q_2)^2 \, C_2}{2(C_1 + C_2)}$$

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Section 2 **Quiz 4** **10 March 2011**

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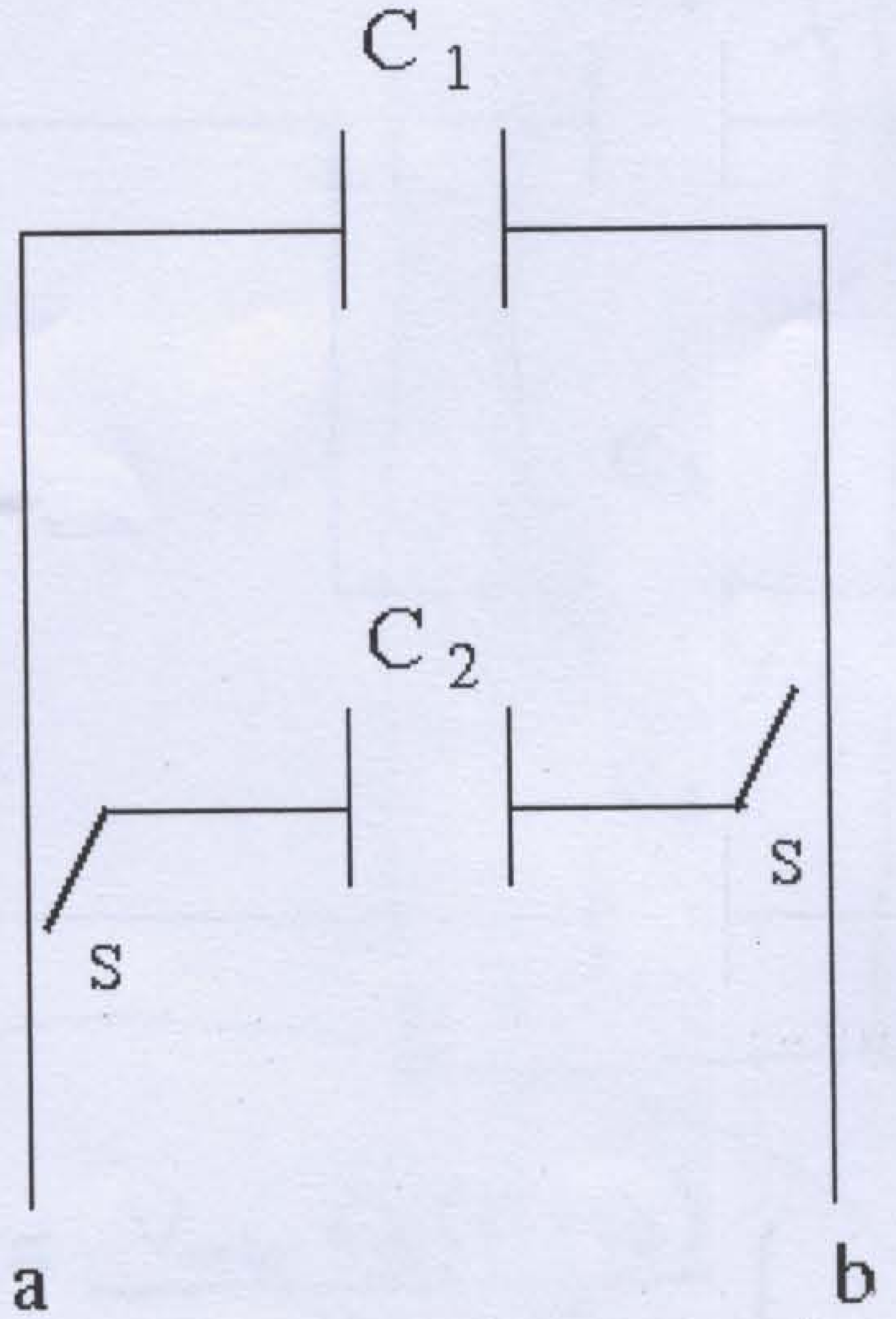
Quiz duration: 10 minutes

Name: **Student ID:** **Signature:**

Initially the switches (labeled by S) are open, and the electric potential difference between the "a" and "b" terminals is measured to be "V". After switches are closed an uncharged capacitor (C_2) is connected to the circuit as shown in the figure. Calculate the energy stored in the second capacitor (C_2) in terms of the capacitances and V.



* Initially, C_1 is charged and

$$Q_1 = C_1 V$$

* When the switches are closed the total charge on the system is conserved.

$$Q = Q_1 = C_1 V$$

* The potential difference for both capacitors is the same
⇒ They are parallel connected

$C_{eq} = C_1 + C_2$

* Each share the total charge Q wrt ratio of their capacitences

$\frac{Q_{1f}}{Q_{2f}} = \frac{C_1}{C_2}$ & $Q_{1f} + Q_{2f} = Q_1 = C_1 V \Rightarrow Q_{2f} = \frac{C_1 C_2 V}{C_1 + C_2}$

* Energy stored: $U = Q^2/2C \Rightarrow U_{2f} = Q_{2f}^2/2C_2 = \boxed{C_1^2 C_2 V^2/2(C_1+C_2)^2}$

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Section 3 **Quiz 4** **10 March 2011**

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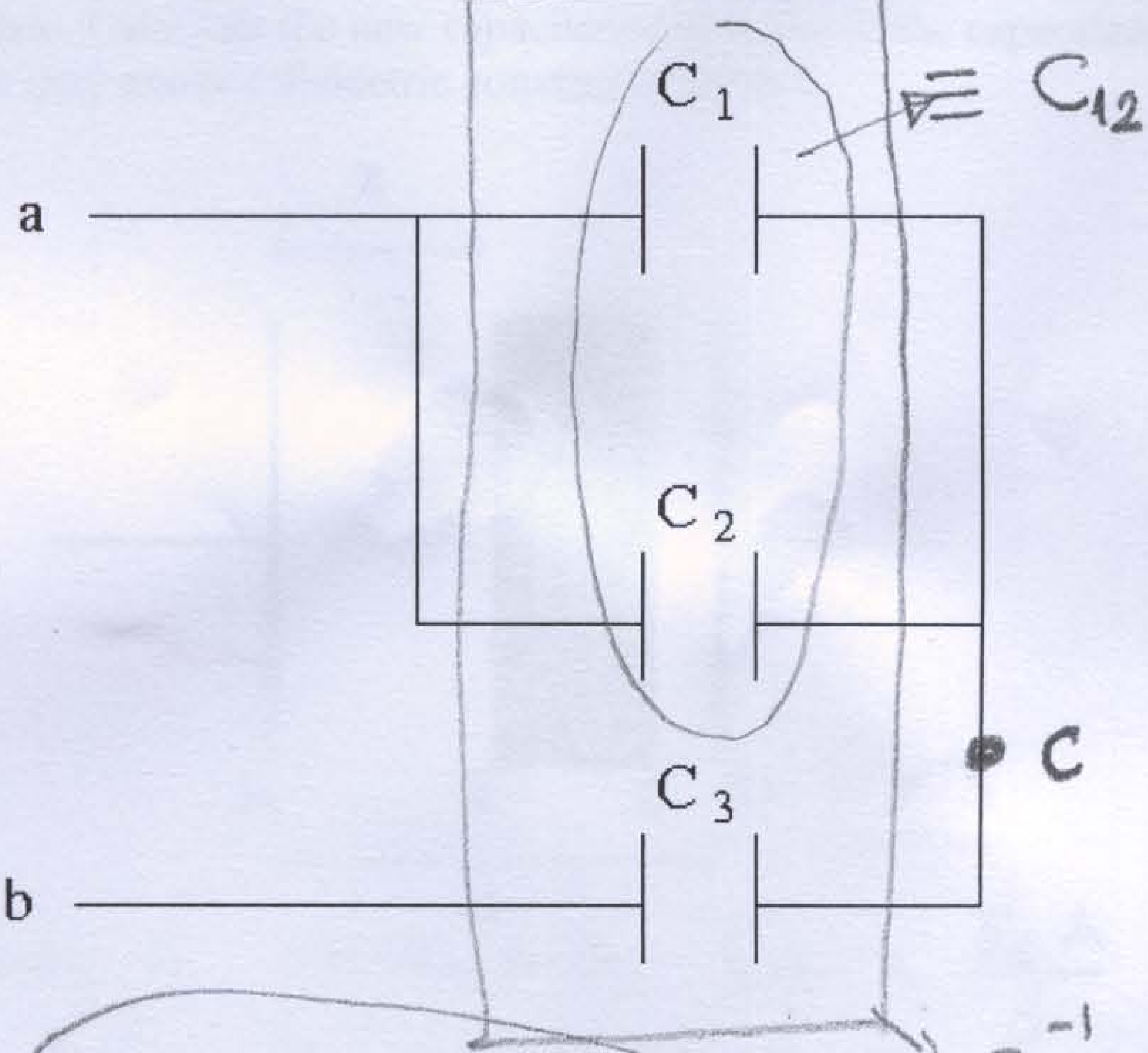
Quiz duration: 10 minutes

Name: **Student ID:** **Signature:**

The terminals "a" and "b" are connected to a battery. After a long time if the energy stored in the first capacitor (C_1) is found to be "U", how much energy is stored on the third capacitor(C_3)? Express your result in terms of the capacitances and U.



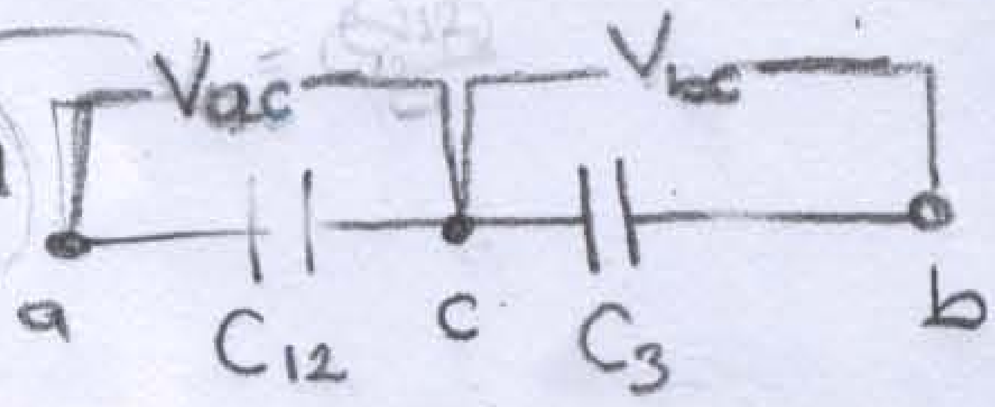
$\equiv C_{12} = C_1 + C_2$

$C = \frac{Q}{V}$

$C_{eq}^{-1} = C_{12}^{-1} + C_3^{-1} = \frac{1}{C_1+C_2} + \frac{1}{C_3}$

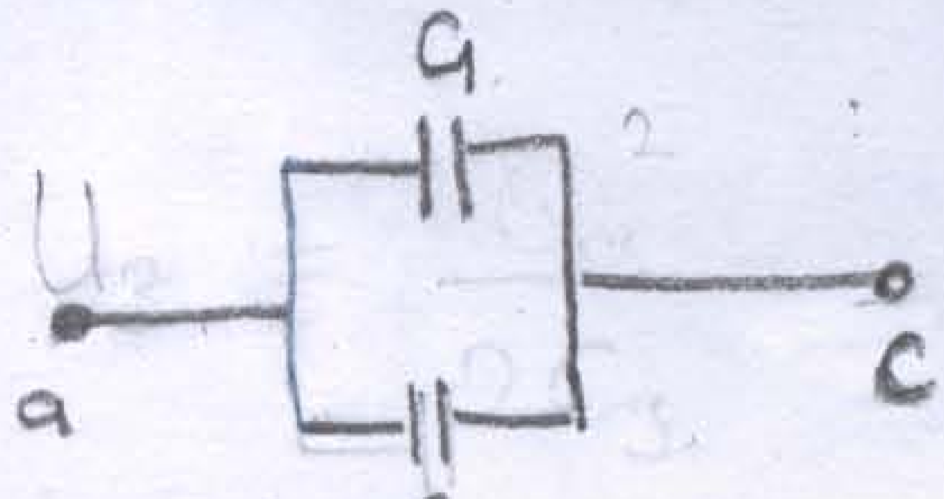
$* \; Q_{eq} = V_{ab} \cdot C_{eq} = \frac{V_{ab}\, C_3 (C_1+C_2)}{C_1 + C_2 + C_3}$

$V_{ac} = \frac{Q_{eq}}{C_{12}}$



connected in series!
⇓
each has the same charge; Q_{eq}

$C_{eq} = \frac{C_3 (C_1+C_2)}{C_1 + C_2 + C_3}$



connected in parallel → kept in same potential (V_{ac})

$Q_1 = C_1 V_{ac} = C_1 \frac{Q_{eq}}{C_{12}} = \frac{V_{ab} \cdot C_1 \cdot C_2}{C_1 + C_2 + C_3}$

$U_1 = \frac{Q_1^2}{2C_1} = \boxed{\frac{V_{ab}^2 C_2^2 C_1}{2(C_1+C_2+C_3)^2} = U}$

* for the 3rd capacitor:

$U_3 = \frac{Q_3^2}{2C_3} = \frac{Q_{eq}^2}{2C_3} = \frac{V_{ab}^2 C_3 (C_1+C_2)^2}{2(C_1+C_2+C_3)^2} = \frac{U}{C_1 C_2^2} C_3 (C_1+C_2)^2$

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Section 4 **Quiz 4** **10 March 2011**

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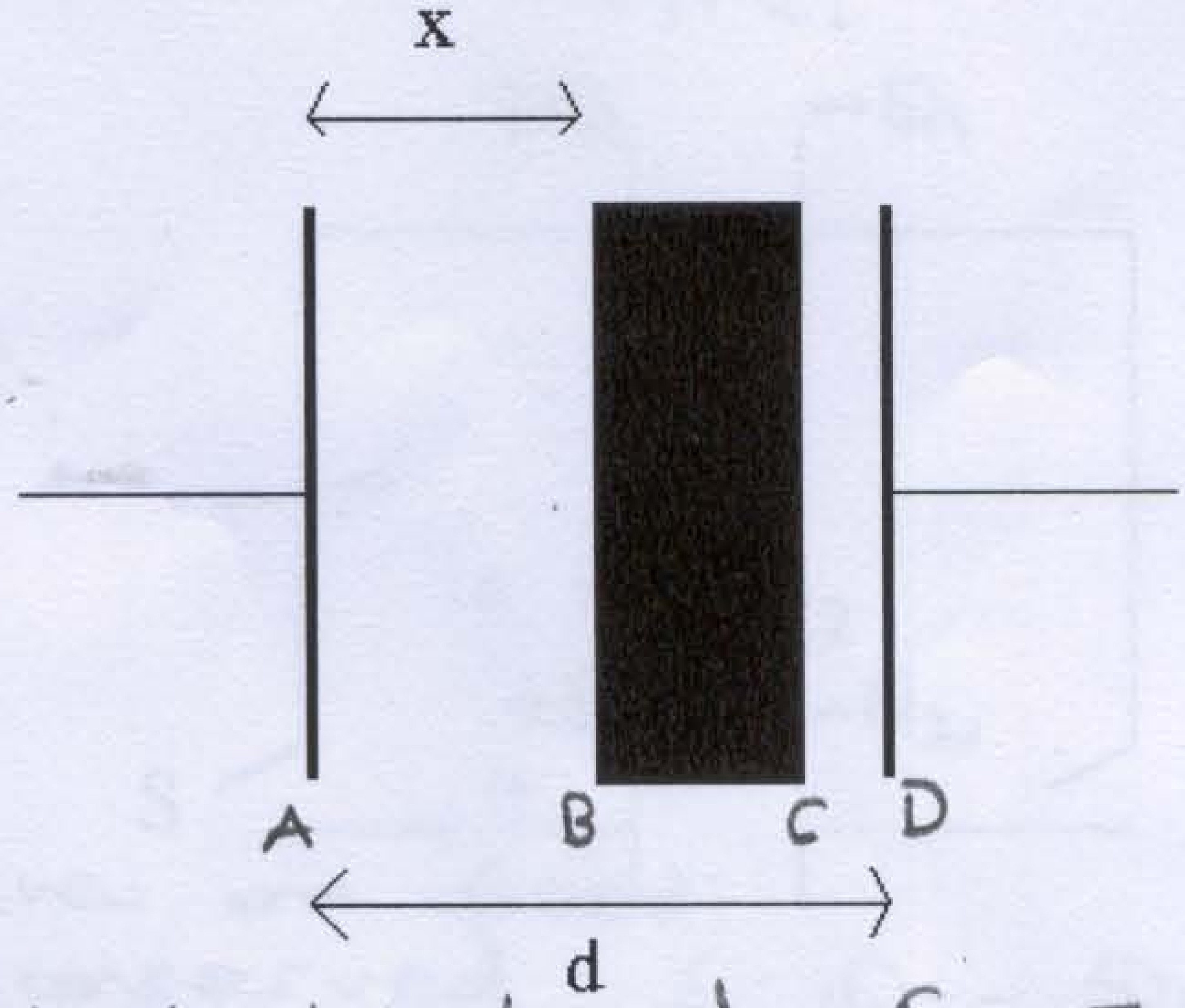
Quiz duration: 10 minutes

Name: **Student ID:** **Signature:**

with dielectric constant, $K=1$ is

A parallel ~~air~~ capacitor is made by using two flat conducting plates, each with area "A", separated by a distance "d". Then a metal slab having thickness "a" and the same shape and size as the plates inserted between them, parallel to the plates and not touching either plate. Calculate the new capacitance in terms of the capacitance of the air capacitor. You may assume dielectric constant of air is 1.



Before the slab is introduced, $C_0 = \frac{\epsilon_0 A}{d}$

When the slab is introduced we need to calculate the new capacitance,

$$C = \frac{Q}{V_{AD}}$$

$$V_{AD} = V_{AB} + V_{BC} + V_{CD} = \int_A^B \vec{E}\cdot d\vec{l} + \cancel{\int_B^C \vec{E}\cdot d\vec{l}} + \int_C^D \vec{E}\cdot dl$$

0 since the field inside the conductor is zero

$$= \frac{\sigma}{\epsilon_0}\cdot d_{AB} + \frac{\sigma}{\epsilon_0} d_{CD} = \frac{\sigma}{\epsilon_0}\underbrace{(d_{AB}+d_{CD})}_{=d-a}$$

$$\Rightarrow C = \frac{Q}{\frac{\sigma}{\epsilon_0}(d-a)} \quad \& \quad \sigma = Q/A \quad \Rightarrow C = \frac{\epsilon_0 A}{d-a} = \left(\frac{d}{d-a}\right)\cdot C_0$$

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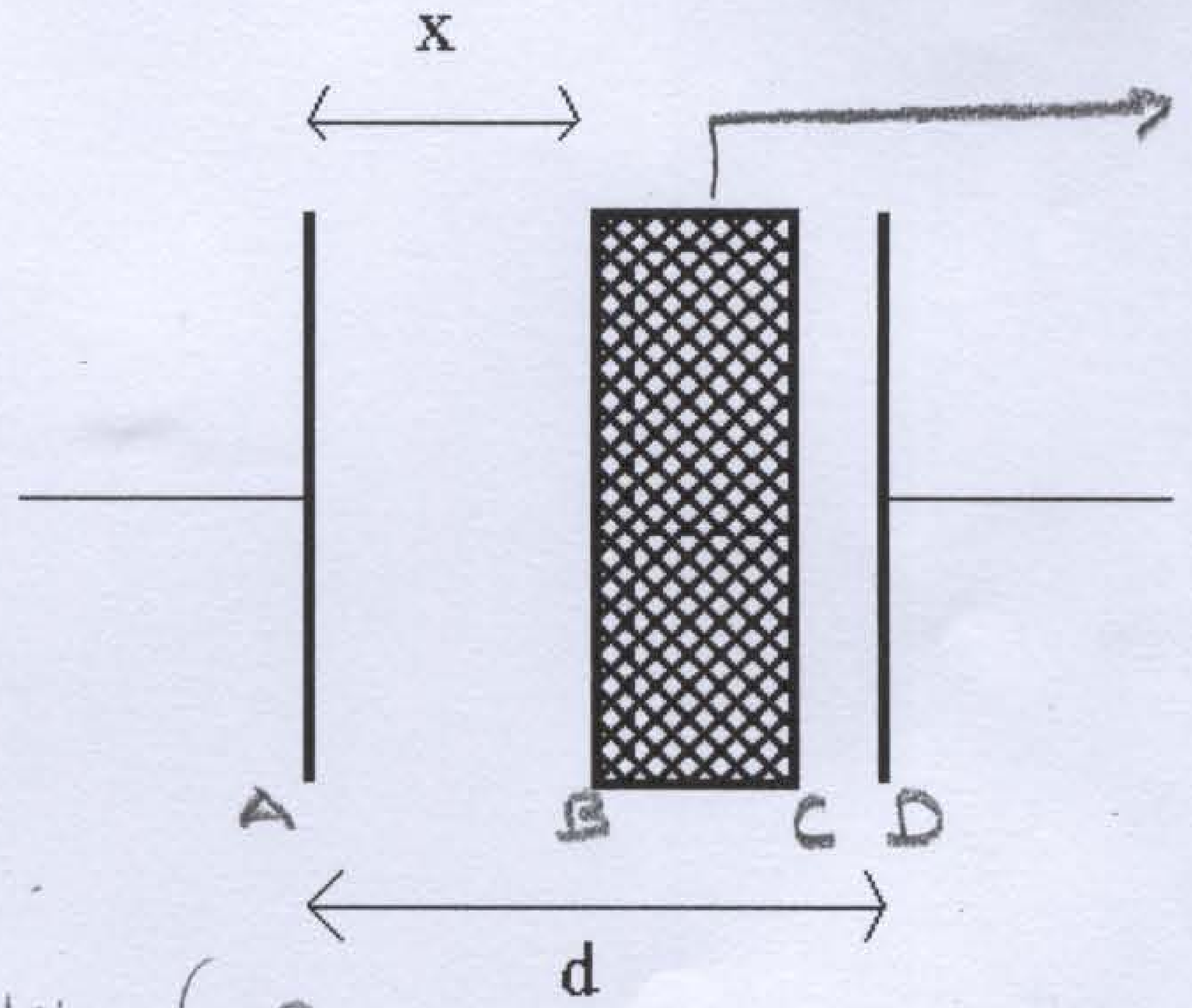
Section 5 Quiz 4 10 March 2011

Closed book. No calculators are to be used for this quiz.
Quiz duration: 10 minutes

Name: **Student ID:** **Signature:**

A parallel ~~air~~ capacitor with dielectric constant $K=1$, is made by using two flat conducting plates, each with area "A", separated by a distance "d". Then a dielectric slab having thickness "a" and the same shape and size as the plates inserted between them, parallel to the plates and not touching either plate. Calculate the new capacitance in terms of the capacitance of the air capacitor. You may assume dielectric constant of air is 1.



$E = K\epsilon_0$

Before the dielectric slab is introduced, $C_0 = \frac{\epsilon_0 A}{d}$

After the slab is introduced,

new capacitance: $C = Q / V_{AD}$

$$V_{AD} = V_{AB} + V_{BC} + V_{CD} = \int_A^B \vec{E}\cdot d\vec{l} + \int_B^C \vec{E}\cdot d\vec{l} + \int_C^D \vec{E}\cdot d\vec{l}$$

$$= \frac{\sigma}{\epsilon_0} d_{AB} + \frac{\sigma}{K\epsilon_0} \cdot a + \frac{\sigma}{\epsilon_0} d_{CD}$$

$$= \frac{\sigma}{\epsilon_0}\Big(\underbrace{d_{AB} + d_{CD}}_{= d-a} + \frac{a}{K} \Big)$$

$$= \frac{\sigma}{\epsilon_0}\left(d + \left(\frac{1}{K} - 1\right) a \right) \quad \& \quad \sigma = Q/A$$

$$\boxed{V_{AD} = \frac{Q}{\epsilon_0 A}\left(d + \left(\frac{1-K}{K}\right) \cdot a \right)}$$

$$C = \frac{\cancel{Q}}{\frac{\cancel{Q}}{\epsilon_0 A}\left[d + \left(\frac{1-K}{K}\right)\cdot a \right]} = \frac{\epsilon_0 A}{\left[d - \left(\frac{K-1}{K}\right) a \right]} = \frac{C_0 d}{d - \left(\frac{K-1}{K}\right) a} = \frac{C_0}{1 - \left(\frac{K-1}{K}\right)\frac{a}{d}}$$