Exam 2: Tuesday, March 21, 5:00-6:00 PM

Test rooms:

Instructor	Sections	Room
Dr. Hale	F, H	104 Physics
Dr. Kurter	B, N	125 BCH
Dr. Madison	K, M	199 Toomey
Dr. Parris	J, L	B-10 Bertelsmeyer*
Mr. Upshaw	A, C, E, G	G-3 Schrenk
Dr. Waddill	D	120 BCH

- Special Accommodations — Testing Center

  (Contact me a.s.a.p. if you need accommodations different than for exam 1)

*new room

Exam 2 will cover chapters 24.3 to 27
(energy stored in capacitors to forces and torques on currents)

Exam Reminders

- 5 multiple choice questions, 4 worked problems
- **bring a calculator** (any calculator that does not communicate with the outside world is OK)
- no external communications, any use of a cell phone, tablet, smartwatch etc. will be considered **cheating**
- no headphones
- be on time, you will not be admitted after 5:15pm

Exam Reminders

- grade spreadsheets will be posted the **day after the exam**
- you will need your **PIN** to find your grade
- test preparation homework 2 is posted on course website, will be discussed in recitation tomorrow
- problems on the test preparation home work are **NOT** guaranteed to cover all topics on the exam!!!

Exam 2 topics

Energy Stored in Capacitors and Electric Fields, Dielectrics

Electric Current, Resistivity and Resistance

EMF, Electric Power

Resistors in Series and Parallel, Kirchhoff's Rules

Electrical Instruments, RC Circuits

Magnetism, Magnetic Forces, Magnetic Flux, Gauss' Law for Magnetism, Motion of Charged Particle in Magnetic Field

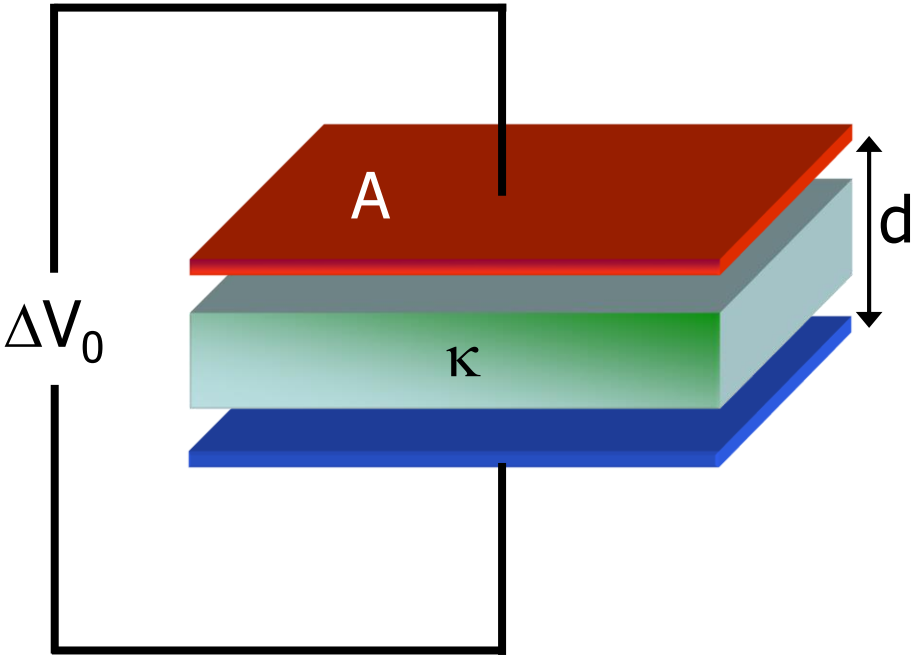
Magnetic Force on Currents, Torque on a Current Loop

Exam 2 topics

- don’t forget the Physics 1135 concepts
- look at old tests (2014 to 2016 tests are on course website)
- exam problems **may come from topics not covered** in test preparation homework or test review lecture

A parallel plate capacitor with plate separation *d* and plate area *A* is charged by connecting it across a potential difference of ΔV_0. A dielectric slab that just fills the space between the plates is inserted between the plates ***while the voltage source remains connected to the plates.***

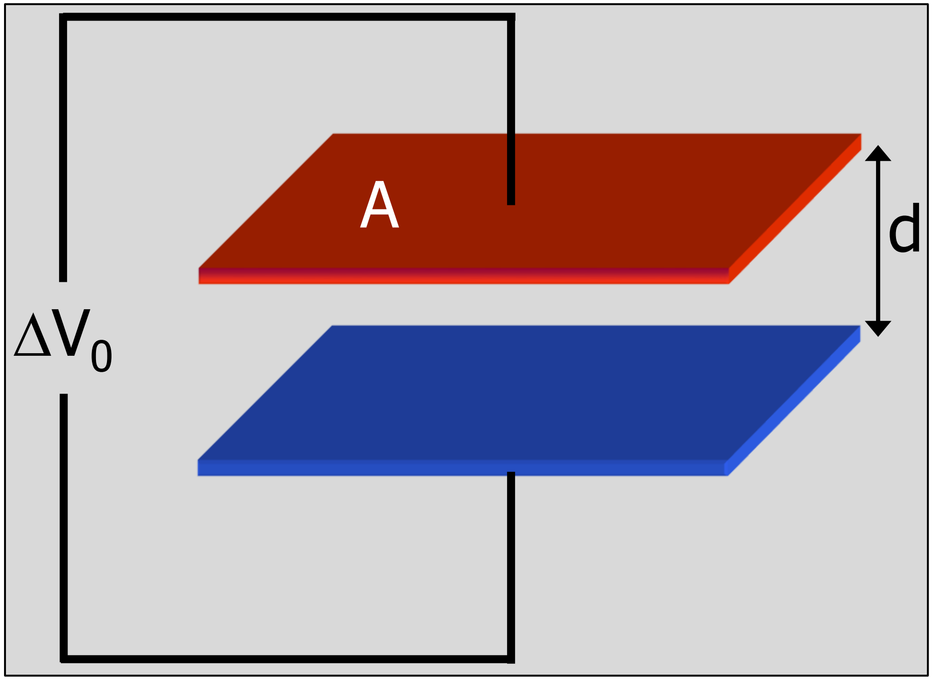
If the energy stored in the capacitor increases by a factor of 4 when the dielectric is inserted, find the dielectric constant κ.



Before:

$$C_0 = \frac{\varepsilon_0 A}{d}$$

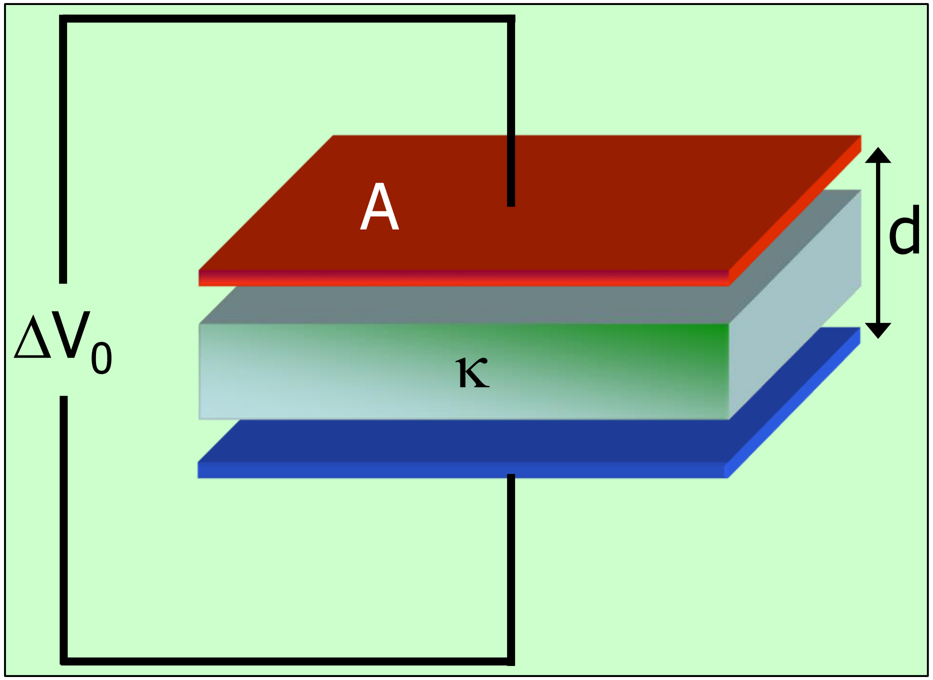
$$U_0 = \frac{1}{2}\left(\frac{\varepsilon_0 A}{d}\right)(\Delta V_0)^2$$



After:

$$C_1 = \frac{\kappa\varepsilon_0 A}{d}$$

$$U_1 = \frac{1}{2}\left(\frac{\kappa\varepsilon_0 A}{d}\right)(\Delta V_0)^2 = 4U_0$$



$$U_1 = 4U_0$$

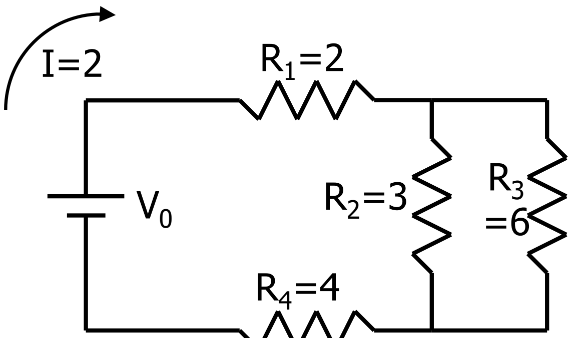
$$\frac{U_1}{U_0} = 4$$

$$\frac{\frac{1}{2}\left(\frac{\kappa\varepsilon_0 A}{d}\right)(\Delta V_0)^2}{\frac{1}{2}\left(\frac{\varepsilon_0 A}{d}\right)(\Delta V_0)^2} = 4$$

$$\boxed{\kappa = 4}$$

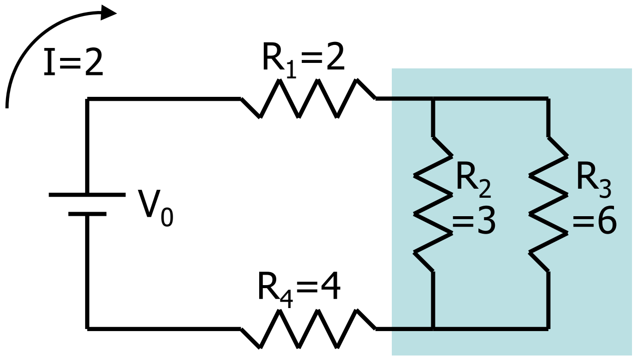
For the system of resistors shown below $R_1=2\Omega$, $R_2=3\Omega$, $R_3=6\Omega$, and $R_4=4\Omega$. If $I=2A$ calculate

(a) the equivalent resistance,
(b) V_0,
(c) the current through each resistor, and
(d) the potential difference across each resistor.



(a) Calculate the equivalent resistance.

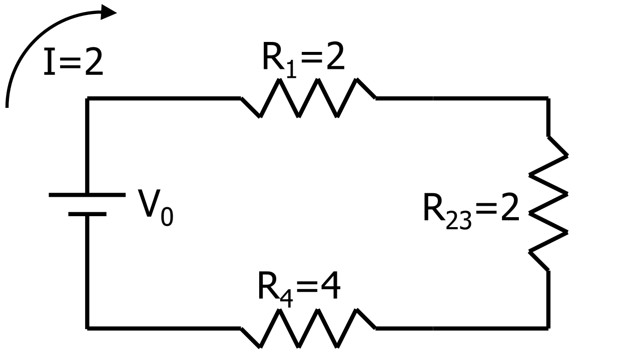
R_2 and R_3 are in parallel.



$$\frac{1}{R_{23}} = \frac{1}{R_2} + \frac{1}{R_3} = \frac{1}{3} + \frac{1}{6} = \frac{3}{6} = \frac{1}{2}$$

$$R_{23} = 2\ \Omega$$

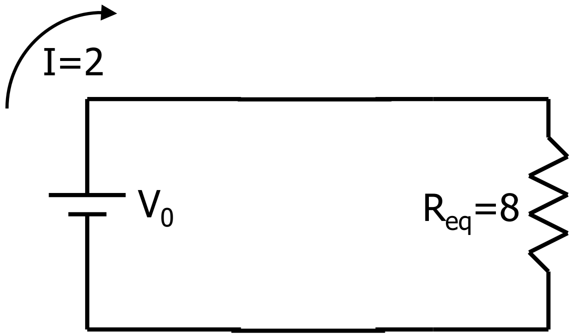
R_1, R_{23}, and R_4 are in series.



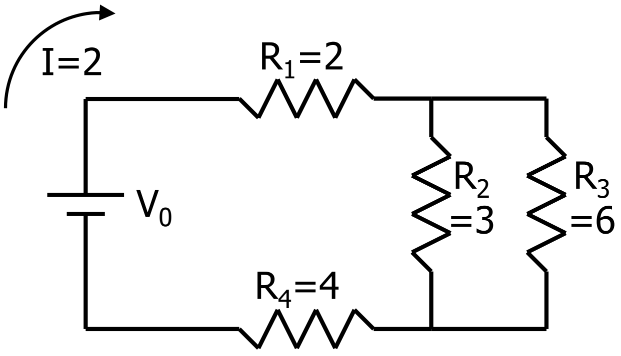
$$R_{eq} = R_1 + R_{23} + R_4 = 2 + 2 + 4 = \boxed{8\ \Omega}$$

(b) Calculate V_0.

$$V_0 = IR_{eq} = (2)(8) = \boxed{16\text{ V}}$$



(c) Calculate the current through each resistor.



$$I_1 = I_4 = \boxed{2\text{ A}}$$

$$V_{23} = IR_{23} = (2)(2) = 4\text{ V} = V_2 = V_3$$

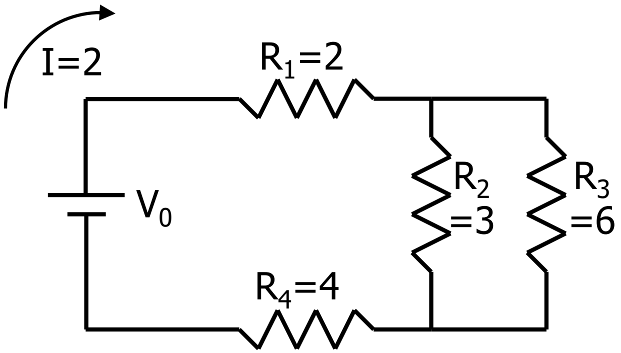
$$I_2 = \frac{V_2}{R_2} = \boxed{\frac{4}{3}\text{A}}$$

$$I_3 = \frac{V_3}{R_3} = \frac{4}{6} = \boxed{\frac{2}{3}\text{A}}$$

Check: $I_2 + I_3 = 4/3 + 2/3 = 2$ A, as it must be.

(d) Calculate the potential difference across each resistor.

$V_1 = IR_1 = (2)(2) = \boxed{4\ \text{V}}$

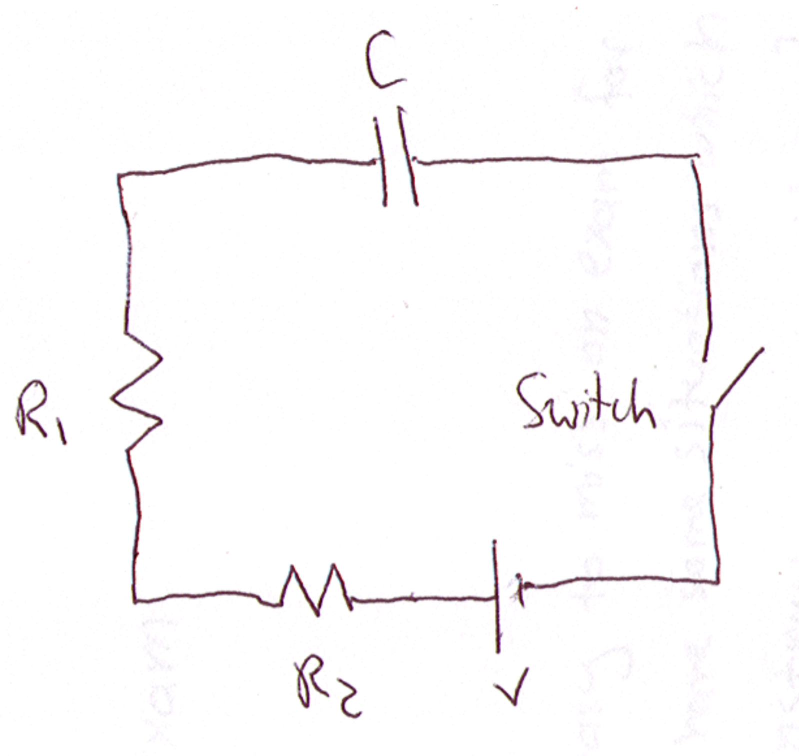


$V_2 = V_3 = \boxed{4\ \text{V}}$ Calculated in part (c).

$V_4 = IR_4 = (2)(4) = \boxed{8\ \text{V}}$

Check: $V_1 + V_{23} + V_4 = 4 + 4 + 8 = 16$ V.
Agrees with part (c).

In the circuit shown R_1=5.0 kΩ, R_2=10 kΩ, and V = 12.0 V. The capacitor is initially uncharged. After the switch has been closed for 1.30 μs the potential difference across the capacitor is 5.0 V. (a) Calculate the time constant of the circuit. (b) Find the value of C. (c) Sketch the current, charge, and potential difference across the capacitor as a function of time.



Someday, when I have time, I will make this into a nice diagram!

2.41×10^{-6} s

0.16 nF

skip to slide 24

In the circuit shown R_1=5.0 kΩ, R_2=10 kΩ, and V = 12.0 V. The capacitor is initially uncharged. After the switch has been closed for 1.30 μs the potential difference across the capacitor is 5.0 V. (a) Calculate the time constant of the circuit..

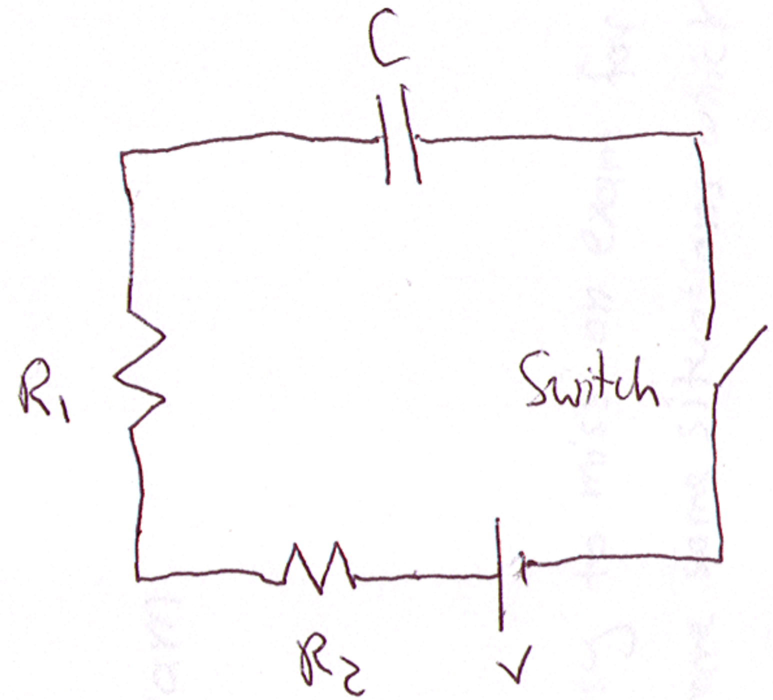
We can't use τ = RC because we don't know C.

We are told the capacitor is charging, and given information about potential difference, so we derive an equation for V(t).

$$q(t) = Q_{final}\left(1 - e^{-\frac{t}{RC}}\right)$$

$$C\,V(t) = C\,V_0\left(1 - e^{-\frac{t}{RC}}\right)$$

$$V(t) = V_0\left(1 - e^{-\frac{t}{RC}}\right)$$



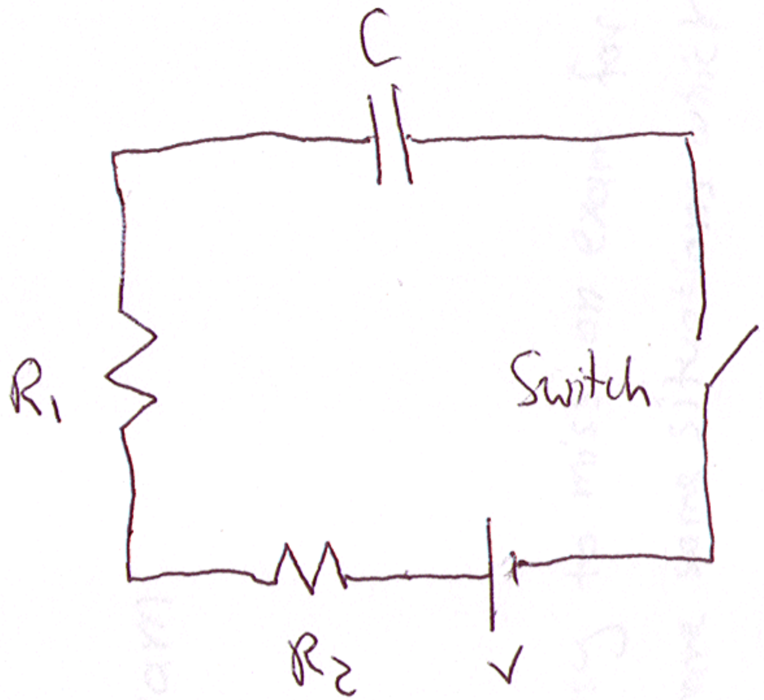
In the circuit shown R_1=5.0 kΩ, R_2=10 kΩ, and V = 12.0 V. The capacitor is initially uncharged. After the switch has been closed for 1.30 μs the potential difference across the capacitor is 5.0 V. (a) Calculate the time constant of the circuit.

Let T = $1.30\text{x}10^{-6}$ s (for simplicity of writing equations).

$$V(T) = V_0\left(1 - e^{-\frac{T}{RC}}\right)$$

$$\frac{V(T)}{V_0} = \left(1 - e^{-\frac{T}{RC}}\right)$$

$$e^{-\frac{T}{RC}} = \left(1 - \frac{V(T)}{V_0}\right)$$



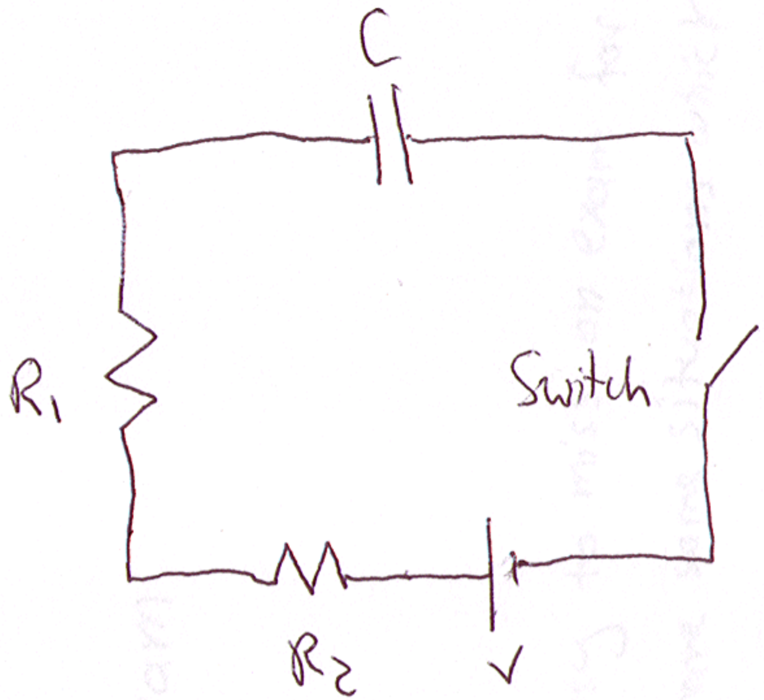
In the circuit shown R_1=5.0 kΩ, R_2=10 kΩ, and V = 12.0 V. The capacitor is initially uncharged. After the switch has been closed for 1.30 μs the potential difference across the capacitor is 5.0 V. (a) Calculate the time constant of the circuit..

$$-\frac{T}{RC} = \ln\left(1 - \frac{V(T)}{V_0}\right)$$

Take natural log of both sides of last equation on previous slide.

$$-\frac{T}{\ln\left(1 - \frac{V(T)}{V_0}\right)} = RC = \tau$$

$$\tau = -\frac{1.3\times10^{-6}}{\ln\left(1 - \frac{5}{12}\right)} = \boxed{2.41\times10^{-6}\text{ s}}$$

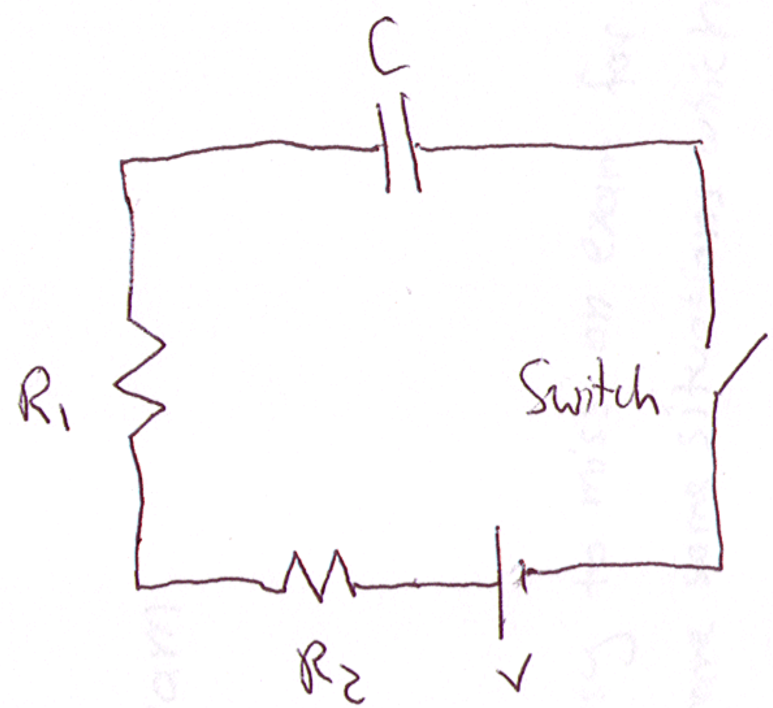


In the circuit shown R_1=5.0 kΩ, R_2=10 kΩ, and V = 12.0 V. The capacitor is initially uncharged. After the switch has been closed for 1.30 μs the potential difference across the capacitor is 5.0 V. (b) Find the value of C.

$$\tau = 2.41 \times 10^{-6}\ \mathrm{s} = RC$$

$$C = \frac{\tau}{R} = \frac{\tau}{(R_1 + R_2)} = \frac{2.41 \times 10^{-6}}{15 \times 10^{3}}$$

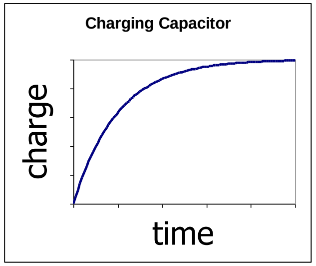
$$C = 0.161 \times 10^{-9}\ \mathrm{F} = \boxed{0.161\ \mathrm{nF}}$$



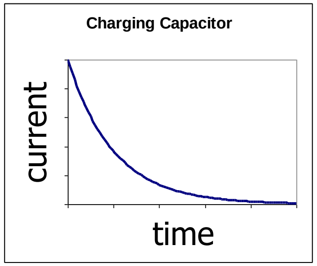
In the circuit shown R_1=5.0 kΩ, R_2=10 kΩ, and V = 12.0 V. The capacitor is initially uncharged. (c) Sketch the current, charge, and potential difference across the capacitor as a function of time.

Charging capacitor (you aren't required to derive these equations):

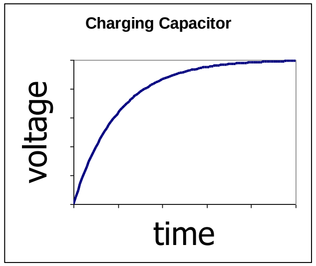
$$q(t) = Q_{final}\left(1 - e^{-\frac{t}{RC}}\right)$$



$$I(t) = \frac{\varepsilon}{R} e^{-\frac{t}{RC}}$$



$$V(t) = \varepsilon\left(1 - e^{-\frac{t}{RC}}\right)$$



In the circuit shown R_1=5.0 kΩ, R_2=10 kΩ, and V = 12.0 V. The capacitor is allowed to fully charge and the battery removed from the circuit. How long does it take for the voltage across the capacitor to drop to ¼ of its fully-charged value?

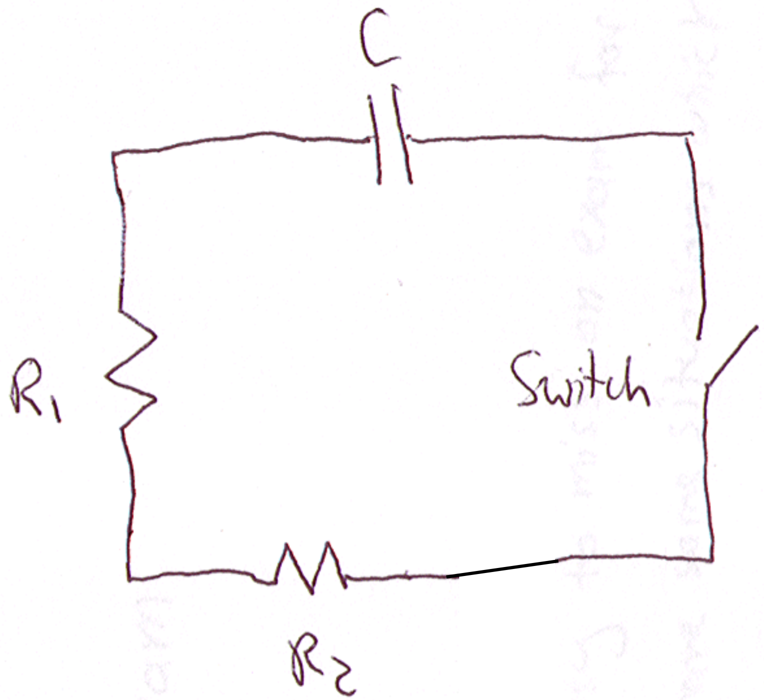
Capacitor has been charged to $Q_{final} = CV_0$ and is now discharging.

$$q(t) = Q_0\, e^{-\frac{t}{RC}}$$

$$CV(t) = CV_0\, e^{-\frac{t}{RC}}$$

$$V(t) = V_0\, e^{-\frac{t}{RC}}$$

$$\frac{V(t)}{V_0} = e^{-\frac{t}{RC}}$$



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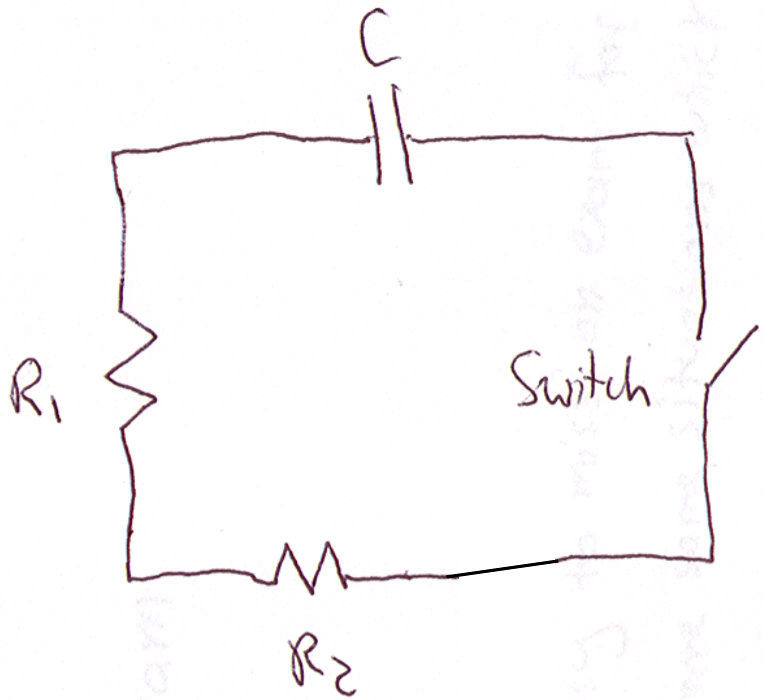
$$\ln\left(\frac{V(t)}{V_0}\right) = -\frac{t}{RC}$$

Take natural log of both sides of last equation on previous slide.

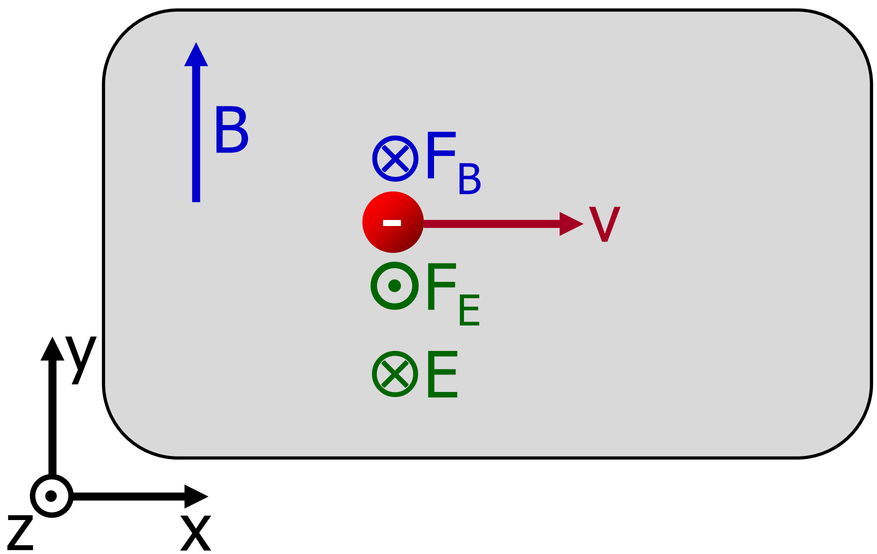
$$t = -RC\ln\left(\frac{V(t)}{V_0}\right) = -\tau\ln\left(\frac{V(t)}{V_0}\right)$$

$$t = -\tau\ln\left(\frac{V_0/4}{V_0}\right) = -\left(2.41\times10^{-6}\right)\ln\left(\frac{1}{4}\right)$$

$$t = 3.34\times10^{-6} = \boxed{3.34\ \mu s}$$



A velocity selector consists of magnetic and electric fields. The magnetic field is described by the expression $\vec{B} = B\hat{j}$. If $B =$ 0.015 T find the magnitude and direction of $\vec{E}$ such that an electron with 750 eV kinetic energy moves along the positive x-axis undeflected.



$$\vec{F}_B = q\vec{v} \times \vec{B} = (-e)v\hat{i} \times B\hat{j} = -evB\hat{k}$$

$\vec{F}_E$ must be in the +z direction, so $\vec{E}$ must be in the –z direction (because the charge on the electron is negative.

$$F_B = |-e|vB = evB \qquad F_E = qE = |-e|E = eE$$

$$F_B = F_E \quad \Rightarrow \quad evB = eE$$

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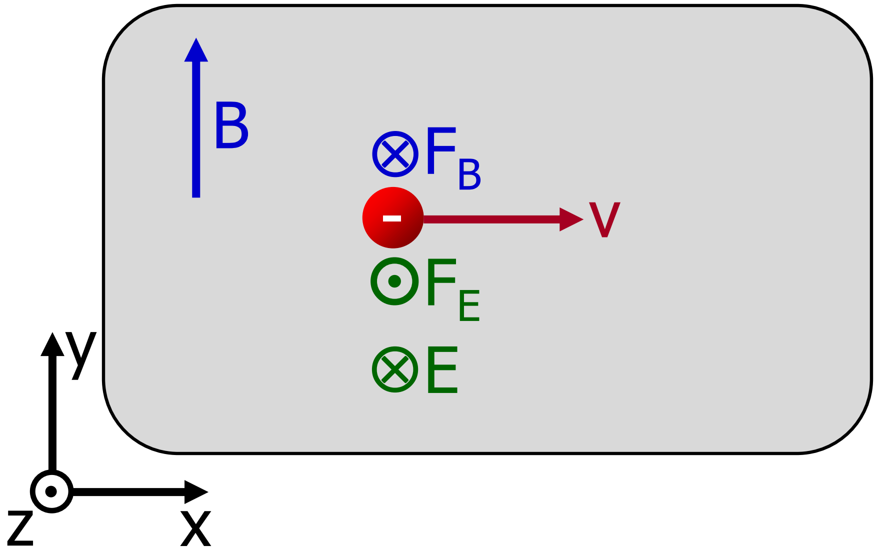


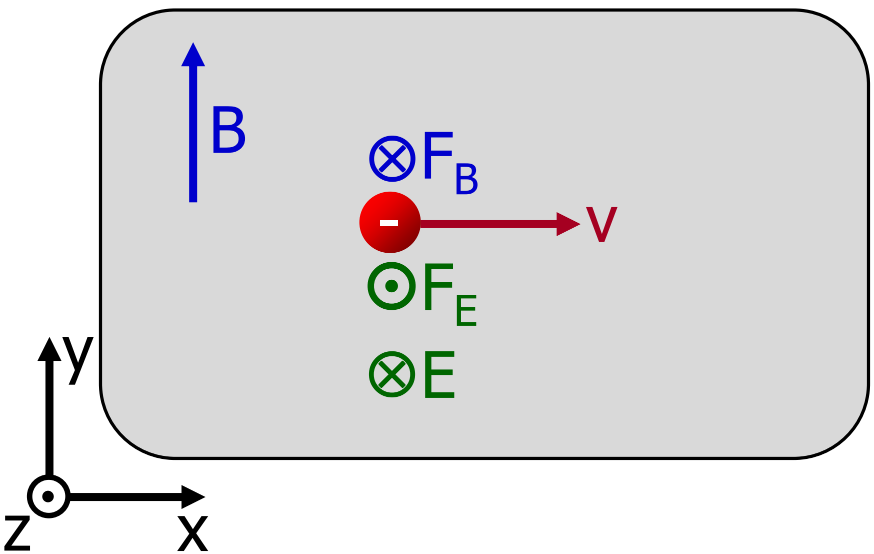
$$evB = eE$$

$$E = vB$$

$$\frac{1}{2} m_e v^2 = K \quad \Rightarrow \quad v = \sqrt{\frac{2K}{m_e}}$$

$$E = B\sqrt{\frac{2K}{m_e}}$$

A velocity selector consists of magnetic and electric fields. The magnetic field is described by the expression $\vec{B} = B\hat{j}$. If $B =$ 0.015 T find the magnitude and direction of $\vec{E}$ such that an electron with 750 eV kinetic energy moves along the positive x-axis undeflected.



$$E = B\sqrt{\frac{2K}{m_e}}$$

don't forget to convert eV to J

$$E = (0.015)\sqrt{\frac{2\left(750\times1.6\times10^{-19}\right)}{9.11\times10^{-31}}}$$

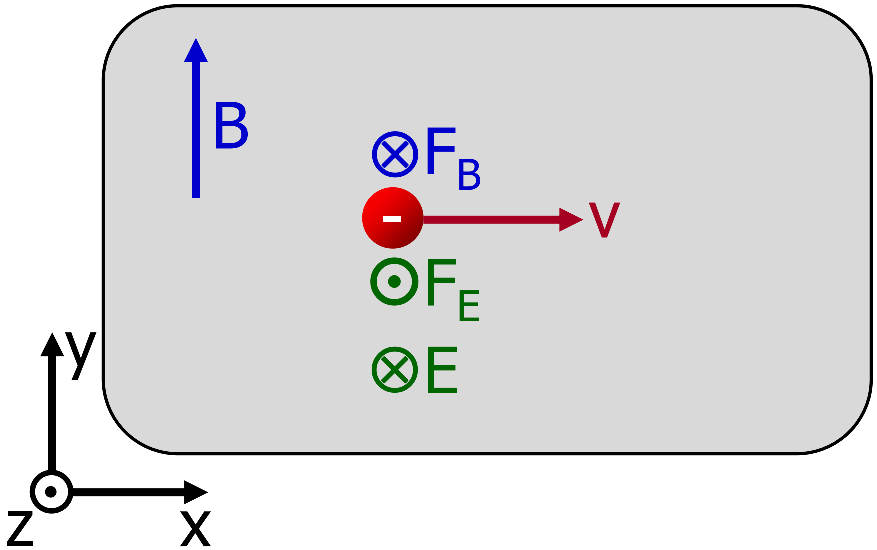
$$E = (0.015)\left(1.623\times10^{7}\right)$$

this is speed in m/s; getting close to relativistic

electron mass is on OSE sheet

$$E = 2.43\times10^{5}\ \frac{N}{C}$$

A velocity selector consists of magnetic and electric fields. The magnetic field is described by the expression $\vec{B} = B\hat{j}$. If $B =$ 0.015 T find the magnitude and direction of $\vec{E}$ such that an electron with 750 eV kinetic energy moves along the positive x-axis undeflected.



Problem asks for magnitude and direction, so

$$\boxed{E = 2.43 \times 10^5 \ \frac{N}{C}, \text{ in the -z direction}}$$

Also "legal:"

$$E = -\left(2.43 \times 10^5 \ \frac{N}{C}\right)\hat{k}$$

$$E = 2.43 \times 10^5 \ \frac{N}{C}, \text{ into page}$$

$$E = 2.43 \times 10^5 \ \frac{N}{C}, \otimes$$