AFTER I GIVE THE SIGNAL TO BEGIN YOU CAN REMOVE THIS SHEET. DO NOT TURN IT IN!

163fa21t2a – Once the exam has officially started, remove the top sheet. The remaining sheets comprise your exam. It is each student's individual responsibility to ensure the instructor has received her or his completed exam. Any exams not received by the instructor earn zero points. Smart watches, phones, or other devices (except scientific calculators) are not permitted during the exam.

$e = 1.602 \times 10^{-19}\ \mathrm{C}$ $\quad k = 8.99 \times 10^{9}\ \frac{\mathrm{N\cdot m^2}}{\mathrm{C^2}}$ $\quad c = 3.00 \times 10^{8}\ \frac{\mathrm{m}}{\mathrm{s}}$ $\quad \varepsilon_0 = 8.85 \times 10^{-12}\ \frac{\mathrm{C^2}}{\mathrm{N\cdot m^2}}$

$h = 6.626 \times 10^{-34}\ \mathrm{J\cdot s}$ $\quad hc \approx 1240\ \mathrm{eV\cdot nm}$ $\quad \mu_0 = 4\pi \times 10^{-7}\ \frac{\mathrm{T\cdot m}}{\mathrm{A}}$ $\quad 1\ \mathrm{eV} = 1.602 \times 10^{-19}\ \mathrm{J}$

$m_p = 1.673 \times 10^{-27}\ \mathrm{kg}$ $\quad m_e = 9.11 \times 10^{-31}\ \mathrm{kg}$

$\vec{F} = q\vec{E}$ $\quad k = \frac{1}{4\pi\varepsilon_0}$ $\quad \Delta x = v_{ix}t + \frac{1}{2}a_x t^2$ $\quad v_{fx}^2 = v_{ix}^2 + 2a_x\Delta x$

$\vec{F}_{1on2} = \frac{kq_1q_2}{r_{12}^2}\hat{r}_{1to2}$ $\quad \vec{E} = \frac{kq}{r^2}\hat{r}$ $\quad V = \frac{kq}{r}$ $\quad U_{12} = \frac{kq_1q_2}{r_{12}}$

$\oint \vec{E}\cdot d\vec{A} = \frac{q_{enc}}{\varepsilon_0}$ $\quad q_{enc} = \int \rho dV$ $\quad E_{\parallel\, plates} = \frac{|\Delta V|}{d} = \frac{\sigma}{\varepsilon_0}$ $\quad E_{plate} = \frac{\sigma}{2\varepsilon_0}$

$E_{ring} = \frac{kQz}{(R^2+z^2)^{3/2}}$ $\quad V_{ring} = \frac{kQ}{(R^2+z^2)^{1/2}}$ $\quad E_x = -\frac{dV}{dx}$ $\quad V_b - V_a = -\int_a^b \vec{E}\cdot d\vec{s}$

$\Delta U = q\Delta V$ $\quad U_C = \frac{1}{2}Q_C\Delta V_C$ $\quad Q_C = \Delta V_C C$ $\quad I_C = -C\frac{dV_C}{dt}$

$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \cdots$ $\quad C_{eq} = C_1 + C_2 + \cdots$ $\quad C_{plates} = \frac{\varepsilon_0 A}{d}$ $\quad C' = \kappa C$

$R_{eq} = R_1 + R_2 + \cdots$ $\quad \frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \cdots$ $\quad R = \frac{\rho L}{A}$ $\quad \rho = \rho_0(1 + \alpha\Delta T)$

$\Delta V_R = I_R R$ $\quad \mathcal{P}_R = I_R \Delta V_R$ $\quad X(t) = X_f + (X_i - X_f)e^{-t/\tau}$ where $\tau = RC$ or $\frac{L}{R}$

$\vec{F} = q\vec{v}\times\vec{B}_{ext}$ $\quad \vec{F} = I\int d\vec{s}\times\vec{B}_{ext}$ $\quad \vec{\tau} = \vec{\mu}\times\vec{B}_{ext}$ $\quad \vec{\mu} = NI\vec{A}$

$U = -\vec{\mu}\cdot\vec{B}_{ext}$ $\quad B_{sol} = \frac{\mu_0 NI}{L}$ $\quad B_{circle} = \frac{\mu_0 I}{2a}$ $\quad B_{straight} = \frac{\mu_0 I}{2\pi a}$

$\oint \vec{B}\cdot d\vec{s} = \mu_0 I_{enc}$ $\quad I_{enc} = \int \vec{J}\cdot d\vec{A}$ $\quad \vec{B} = \frac{\mu_0 I}{4\pi}\int\frac{d\vec{s}\times\hat{r}}{r^2}$ $\quad \Phi_B = \int \vec{B}\cdot d\vec{A}$

$EMF = -N\frac{d}{dt}\Phi_B$ $\quad EMF = B_\perp L v$ $\quad L = \frac{\Phi_B}{I}$ $\quad U_L = \frac{1}{2}LI^2$

$\frac{\Delta V_2}{\Delta V_1} = \frac{N_2}{N_1}$ $\quad \Delta V_L = -L\frac{dI_L}{dt}$ $\quad Z = \sqrt{R^2 + (X_L - X_C)^2}$ $\quad \tan\phi = \frac{X_L - X_C}{R}$

$X_L = \omega L$ $\quad X_C = \frac{1}{\omega C}$ $\quad V_{source} = V_0 \sin\omega t$ $\quad i = i_{max}\sin(\omega t - \phi)$

$\Delta V_{Rmax} = i_{max}R$ $\quad \Delta V_{Lmax} = i_{max}X_L$ $\quad \Delta V_{Cmax} = i_{max}X_C$ $\quad V_{source\ max} = i_{max}Z$

$\Delta V_{max} = \frac{\Delta V_{pk-pk}}{2}$ $\quad \Delta V_{rms} = \frac{\Delta V_{max}}{\sqrt{2}}$ $\quad \omega_0 = \frac{1}{\sqrt{LC}}$

$\mathcal{P}_{avg} = I_{rms}\Delta V_{rms}\cos\phi = I_{rms}^2 R$

$c = f\lambda$ $\quad k = \frac{2\pi}{\lambda}$ $\quad \omega = 2\pi f = \frac{2\pi}{\mathbb{T}}$

$\vec{S} = \frac{\vec{E}\times\vec{B}}{\mu_0}$ $\quad I_{avg} = S_{avg} = \frac{E_{max}B_{max}}{2\mu_0} = \left(\frac{1}{c}\right)\frac{E_{max}^2}{2\mu_0} = c\frac{B_{max}^2}{2\mu_0}$

$\frac{E_{max}}{B_{max}} = c$ $\quad E_\gamma = hf = \frac{hc}{\lambda}$

$Rad.Pressure = \frac{Force}{Area} = \frac{S_{avg}}{c}$ $\quad Photon\ momentum = p_\gamma = \frac{E_\gamma}{c}$

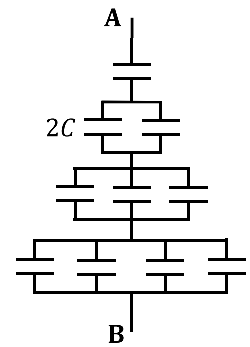
Material	Resistivity at 20° C (in SI units)	Temp. Coefficient (in SI units)
Silver	1.62×10^{-8}	4.1×10^{-3}
Copper	1.69×10^{-8}	4.3×10^{-3}
Aluminum	2.75×10^{-8}	4.4×10^{-3}
Nichrome	1.00×10^{-6}	0.4×10^{-3}
Carbon	3.5×10^{-5}	-0.5×10^{-3}
Germanium	0.46	-48×10^{-3}

$\int\frac{x\,dx}{(x^2+a^2)^{3/2}} = \frac{-1}{\sqrt{x^2+a^2}}$	$\int\frac{dx}{\sqrt{x^2\pm a^2}} = \ln\left\lvert x + \sqrt{x^2\pm a^2}\right\rvert$
$\int\frac{dx}{(x^2+a^2)^{3/2}} = \frac{x}{a^2\sqrt{x^2+a^2}} = \frac{1}{a^2}\sin\theta$	$\int\frac{x\,dx}{\sqrt{x^2\pm a^2}} = \sqrt{x^2\pm a^2}$
$\int\frac{dx}{x^2+a^2} = \frac{1}{a}\tan^{-1}\frac{x}{a}$	$\int\sqrt{x^2\pm a^2}\,dx = \frac{1}{2}x\sqrt{x^2\pm a^2} \pm \frac{a^2}{2}\ln\left\lvert x + \sqrt{x^2\pm a^2}\right\rvert$
$\int\frac{x\,dx}{x^2+a^2} = \frac{1}{2}\ln\lvert x^2+a^2\rvert$	**Binomial expansion:** $(1\pm\delta)^n \approx 1 \pm n\delta + \cdots$

T = 10^{12}	G = 10^{9}	M = 10^{6}	k = 10^{3}	c = 10^{-2}	m = 10^{-3}	μ = 10^{-6}	n = 10^{-9}	p = 10^{-12}	f = 10^{-15}	a = 10^{-18}

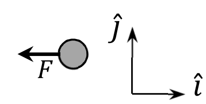
WRITE YOUR NAME AT THE TOP OF THIS PAGE!

The capacitor network at right has one capacitor with capacitance $2C$.
Each of the other capacitors in the network have capacitance C.
1) Determine the equivalent capacitance of this network (between points **A & **B**).
Express your answer as a decimal number with 3 sig figs times C.



1	

A negatively charged particle moves with speed v into the page. The force caused by a uniform external magnetic field points to the left. For each of the following questions, circle the answer which best relates to each component of the external magnetic field.



2a) The $\hat{\imath}$ component of the magnetic field…

Must be positive.	*Must* be zero.	Must be non-zero, but it is unclear if it should be positive or negative.
Must be negative.	*Could* be non-zero since it has no effect on force at instant shown.	None of the other answers is correct.

2b) The $\hat{\jmath}$ component of the magnetic field…

Must be positive.	*Must* be zero.	Must be non-zero, but it is unclear if it should be positive or negative.
Must be negative.	*Could* be non-zero since it has no effect on force at instant shown.	None of the other answers is correct.

2c) The $\hat{k}$ component of the magnetic field…

Must be positive.	*Must* be zero.	Must be non-zero, but it is unclear if it should be positive or negative.
Must be negative.	*Could* be non-zero since it has no effect on force at instant shown.	None of the other answers is correct.

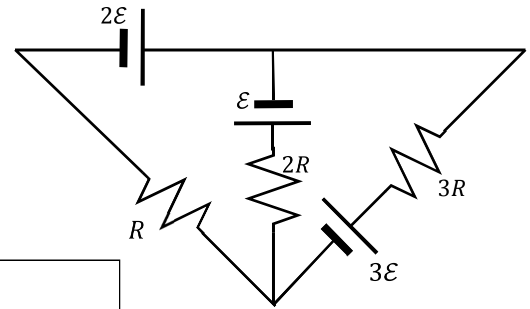
A circuit is labled with known quantities at right.

***3a) Write an appropriate set of linearly independent equations *in the box below* for analyzing this circuit. Please label the figure at right as described in class or you will receive zero credit for this part.

***3b) Determine power delivered to the smallest resistance.

I will award almost no partial credit for this part.

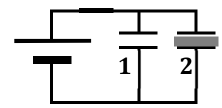
Answer as a number with 3 sig figs times $\frac{\mathcal{E}^2}{R}$.

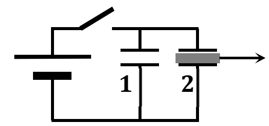


3a	

3b	

A circuit is connected as shown at right. Capacitor 2 is identical in size & shape to capacitor 1 but it is filled with a dielectric material with constant $\kappa = 1.75$. The capacitors are allowed to reach full charge then the switch is opened. After the switch is opened, the dielectric is removed from capacitor 2.





4a) Once the dielectric is removed, how does equivalent capacitance of the combination of capacitors 1 and 2 change? Circle the best answer.

Increases	Decreases	Stays constant	Impossible to determine without more info

4b) Once the dielectric is removed, how does *charge on capacitor 1* change?

Increases	Decreases	Stays constant	Impossible to determine without more info

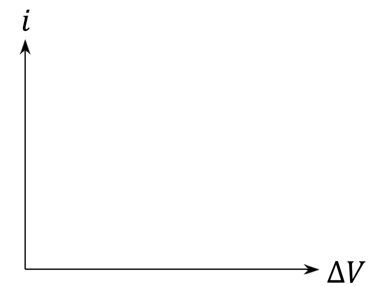
4c) Once the dielectric is removed, how does *voltage across capacitor 2* change?

Increases	Decreases	Stays constant	Impossible to determine without more info

****4d) Determine the percent change in energy. To be clear, by *initial* energy I mean the energy associated with the fully charged caps *before* the dielectric is removed. *Final* energy implies *after* the dielectric is removed.
Write your answer as a number with 3 sig figs.
If energy decreases, I expect a negative sign on the answer.

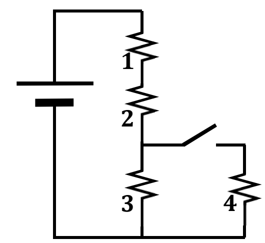
4d	

**5) A cylindrical *carbon* wire is connected to a power supply. The voltage across the wire is gradually increased. As the voltage applied across the wire increases, significant heating occurs. Sketch a plausible plot of current versus voltage for the carbon wire for the voltages described in this scenario.



***6) A circuit is built from four identical resistors as shown at right. The resistors are numbered for ease of communication. Initially the switch is in the open position.
By what numerical factor does the power to resistor 1 change (when the switch is closed)?

- If there is no change to the power delivered to resistor 1, the factor is 1.
- If the power increases, I'm expecting a factor larger than 1.
- If the power decreases, I'm expecting a factor less than 1.



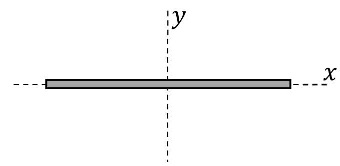
5	

A wire segment of length L is centered at the origin and carries current I flowing to the left.
An external field is given by $\vec{B} = \alpha x^2 \hat{k}$ where α is a positive constant.

7a) Determine the units appropriate for the constant α.

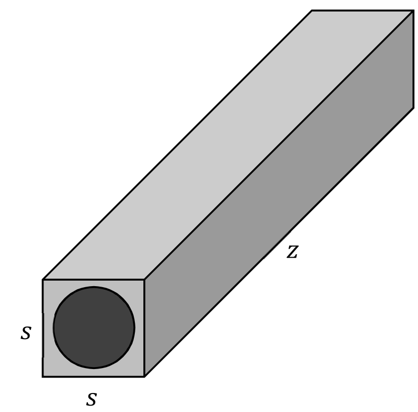
7b) Determine the *direction* of the *net* magnetic force on the wire.
If no net magnetic force, answer "no net force".

***7c) Determine the magnitude of *net* magnetic force on the wire.
If the answer is zero, show substantial work supporting your claim.
If the answer is non-zero, simplify your work for full credit.



7a	
7b	
7c	

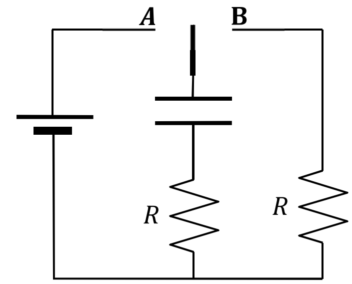
A rectangular solid of aluminum has a cylindrical hole drilled through its entire length. The electrical resistance between the front and back faces (faces with circular holes) is 333 μΩ at standard room temperature 20.0℃. Dimensions for the piece of metal are $z = 77.7$ cm and $s = 11.10$ mm (figure not to scale). For reference, aluminum has a boiling point of 2470℃ while the melting point is 660℃.



****8a) Determine the diameter of the cylindrical hole.
Hint: first produce an *algebraic* solution to ensure maximum partial credit (in the event you screw up plugging in the numbers).
**8b) Determine the maximum resistance possible between the front & back faces.

8a	
8b	

An RC circuit with capacitance 567 nF is shown at right.
The two resistors in the circuit are identical but have unknown resistance.
The circuit can charge while in position **A** and discharge while in position **B**.
Internal resistance of the battery is negligible.
A plot of capacitor charge versus time is shown for this circuit.

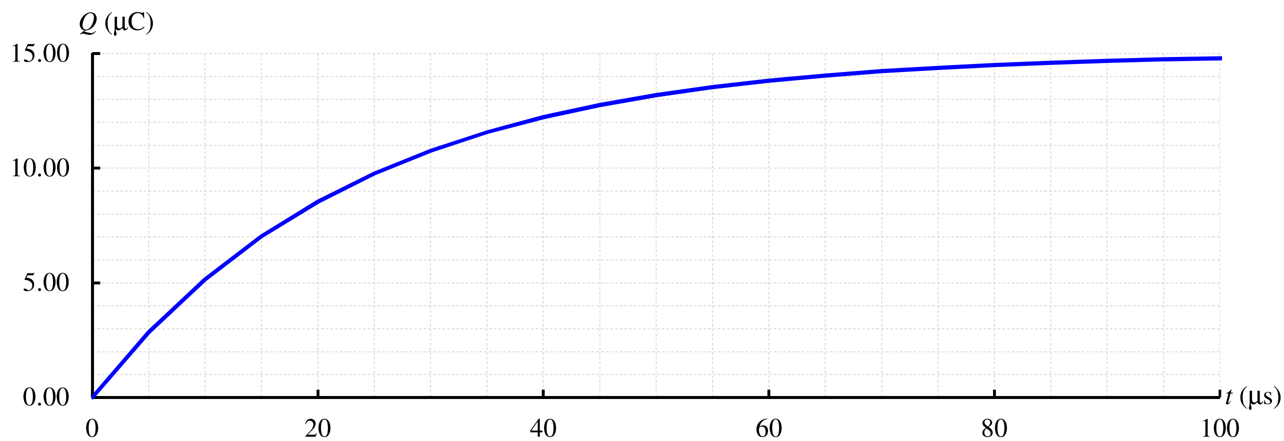


9a) Which occurs more rapidly: charging or discharging?

Charging is more rapid	Discharging is more rapid	Charging & discharging happen at same rate	Impossible to determine without the value of R

9b) The plot below shows capacitor charge versus time for the circuit shown.
Was this plot made while the circuit was in position **A** or position **B**?

Position **A**	Position **B**	*Neither* scenario could produce such a plot	*Either* scenario could produce such a plot



9c) Determine the battery voltage.
***9d) Determine resistance R. Your answer should be within 10% of mine.

9c	
9d	

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