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

163fa22 Exam 2A – 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 $\frac{L}{R}$

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

$U = -\vec{\mu} \cdot \vec{B}_{ext}$ $\quad B_{sol} = \frac{\mu_0 NI}{L}$ $\quad B_{ring} = \frac{\mu_0 I r^2}{2(r^2+z^2)^{3/2}}$ $\quad B_{straight} = \frac{\mu_0 I}{2\pi a}$

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

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

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

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

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

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

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

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

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

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

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

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:** $(1 \pm \delta)^n \approx 1 \pm n\delta + \cdots$

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

WRITE YOUR NAME AT THE TOP OF THIS PAGE!

A wire with a square cross-section has length 33.3 cm, resistivity 888 nΩ·m, and resistance of 2.22 Ω at *room* temperature (20.0℃). Eventually, current flow in the wire heats up the wire. Eventually, the wire's temperature stabilizes at 585℃. At this new temperature the wire's resistance increases by 42.5% (compared to the room temp level).

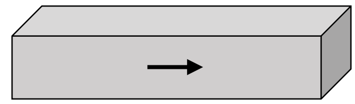
1a) Is the material most likely a metal or a semi-conductor?

**1b) Determine the *side length* of the wire.

Answer in **engineering notation** with correct **units** and **best choice of prefix**.

**1c) Determine the *temperature coefficient* of resistivity.

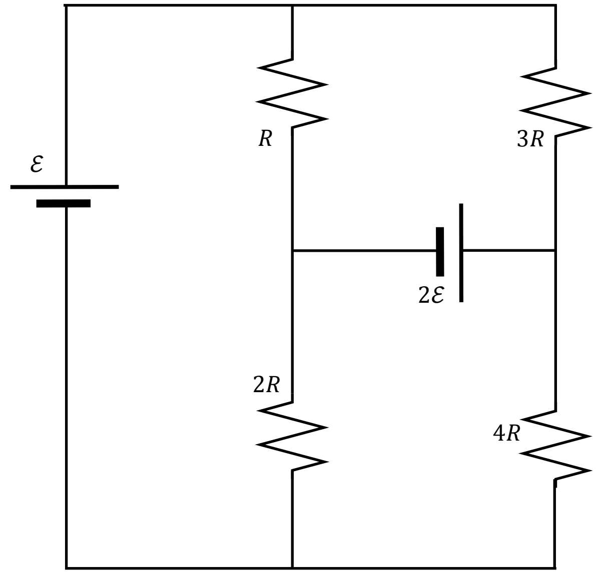
Use scientific notation for this part.



Direction of current in wire

1a	
1b	
1c	

2a) Consider the circuit shown at right. Assume battery voltages and resistances are known. An engineer wishes to compute current through each circuit element (all batteries & all resistors). How many junction & loop equations are required?

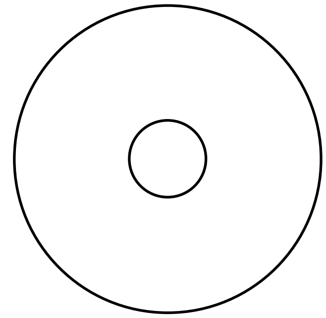


# of Junction Equations	# of Loop equations

*****2b) Label the figure and write a set of equations that could be used to determine all currents. If you include linearly dependent equations you will lose points.

Write the equations but do not solve for anything.

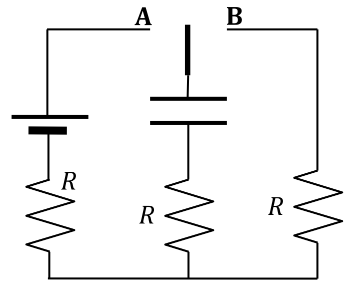
Two spherical shells have radii R & $4R$. The shells are concentric & conducting. The thickness of each shell is negligible. No dielectric is present between the shells. The figure at right shows a cross-sectional view of the shells (not to scale).



*****3) Derive capacitance between the inner and outer shells. For this problem you must show work; writing a memorized answer receives no credit.

3	

An RC circuit with capacitance $C = 4.70$ pF is shown at right.
The switch can be changed between positions **A** and **B**.
Internal resistance of the battery is negligible.

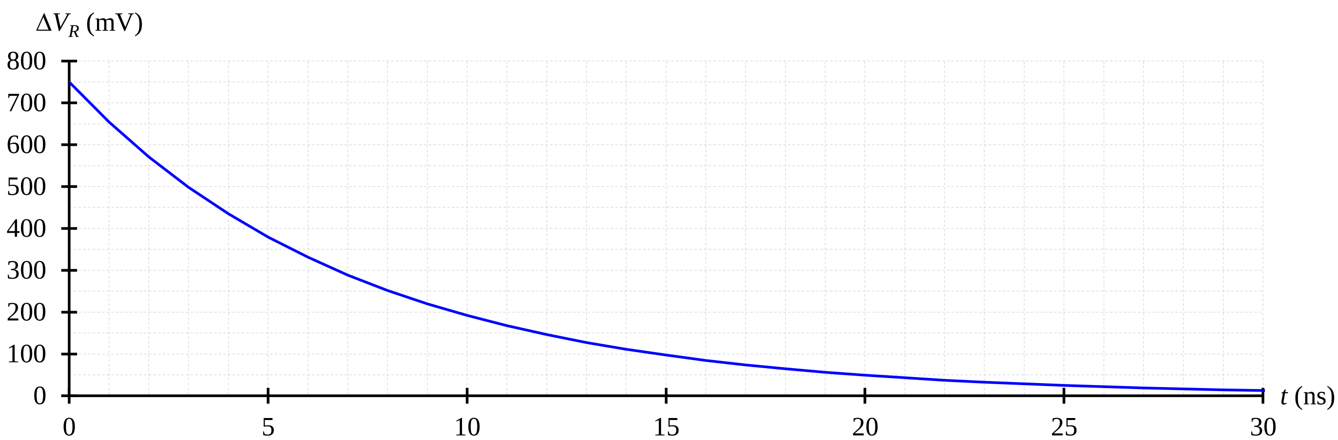


4a) Which occurs more rapidly: charging or discharging?

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

4b) The plot below shows voltage across the resistor in the central branch versus time for the circuit shown. Was this plot made while the circuit was in position **A** or position **B**?

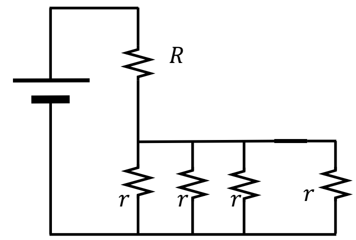
Position **A**	Position **B**	*Neither* switch position produces such a plot	*Either* switch position produces such a plot



***4c) Determine resistance R. Your answer should be within 10% of mine.
4d) Determine *initial* power delivered to the resistor in the central branch.

4c	
4d	

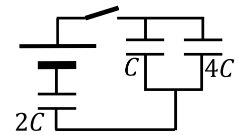
A resistor circuit is built using an ideal battery as shown at right.
Resistance R is known but resistance r is unknown.
When a student opens the switch, she discovers total power delivered by the battery changes by a factor of 0.925.
*****5a) Determine r.
Express your result as a decimal number with 3 sig figs times R.
Use four sig figs if the first digit is a 1.



5a	

5b) Explain conceptually (without math), why it makes sense for the factor to be less than 1 for this scenario. I think 2-3 sentences is plenty to do a good job here.

A capacitor network is constructed using an ideal battery as shown at right.
The switch is closed at time $t = 0$ and the capacitors rapidly reach steady state.
Capacitor $2C$ can store maximum energy U_2 before failing.



*6a) Which capacitor, C or $4C$, stores more energy once the switch is closed (and the system reaches steady state)? Circle the best answer.

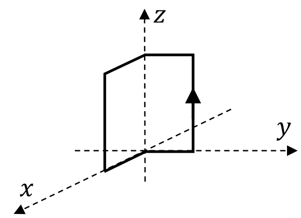
$U_C > U_{4C}$	$U_C = U_{4C}$	$U_C < U_{4C}$	Impossible to determine without more info

**6b) Determine the equivalent capacitance of the capacitor network.
Answer as a decimal with 3 sig figs (or simplified fraction) times C.

***6c) Determine the largest possible battery voltage this circuit can employ without exceeding the energy limitation on $2C$. Assume C & $4C$ never fail for this problem.
Answer with a decimal number with 3 sig figs (or simplified fraction) times an expression with the given variables.

6b	
6c	

A square loop of wire has 50.0 turns and side length 30.0 cm. Note: this loop carries some current (unknown amount, direction indicated in the figure) but no power supply is shown. The loop is bent such that half of the loop lies in the xz-plane and the other half lies in the yz-plane as shown at right. The loop is in the presence of a uniform 725 mT external magnetic field directed parallel to the positive z-axis. The magnitude magnetic torque magnitude acting on the loop is 1.250 N·m. The loop is held in place and does not rotate even though magnetic torque is exerted on it.



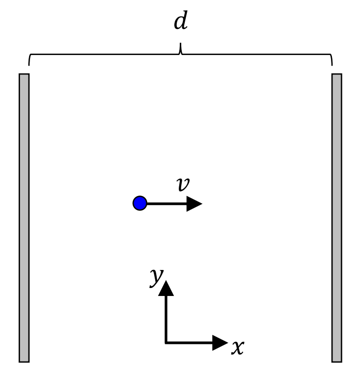
8a) Which best describes the direction of the magnetic moment associated with this loop?

$+\hat{\imath}$	$+\hat{\jmath}$	$+\hat{k}$	Combo of $+\hat{\imath}$ & $+\hat{\jmath}$	Combo of $-\hat{\imath}$ & $+\hat{\jmath}$	Combo of $+\hat{\imath}$ & $+\hat{k}$	Combo of $-\hat{\imath}$ & $+\hat{k}$	Combo of $+\hat{\jmath}$ & $+\hat{k}$	Combo of $-\hat{\jmath}$ & $+\hat{k}$	Impossible to determine without more info
$-\hat{\imath}$	$-\hat{\jmath}$	$+\hat{k}$	Combo of $+\hat{\imath}$ & $-\hat{\jmath}$	Combo of $-\hat{\imath}$ & $-\hat{\jmath}$	Combo of $+\hat{\imath}$ & $-\hat{k}$	Combo of $-\hat{\imath}$ & $-\hat{k}$	Combo of $+\hat{\jmath}$ & $-\hat{k}$	Combo of $-\hat{\jmath}$ & $-\hat{k}$	

*****8b) Determine current in the loop.

8b	

At one particular instant in time, an electron moves horizontally with speed v between two parallel plates (cross section shown at right). The potential difference between the plates is ΔV across plate separation d. Assume the plates have infinite area and negligible fringing fields. A uniform external magnetic field of magnitude B is also present between the plates. **In this special case, we know the magnetic field is aligned with one of the principal axes. At the instant in time shown the electron is speeding up.**



9a) Which or the following statements best describes how the fields relate to the forces speeding up the electron at the instant shown? Circle the best answer.

Magnetic field speeds up electron while electric field does zero work.	Electric field exerts stronger force to the right than the magnetic force to the left.	Magnetic & electric fields both exert forces tending to speed up the electron.
Electric field speeds up electron while magnetic field does zero work.	Magnetic field exerts stronger force to the right than the electric force to the left.	Impossible to determine without knowing the direction of the magnetic field axis.

9b) Just after the instant shown, the electron is observed to deflect out of the page. Which best describes the alignment of the magnetic field?

$+\hat{\imath}$	$+\hat{\jmath}$	$+\hat{k}$	Impossible to determine without more info
$-\hat{\imath}$	$-\hat{\jmath}$	$+\hat{k}$	

9c) Which best describes the trajectory of the electron?

Straight line path	Circular path	Parabolic path	None of the others is correct

9d) Describe how a student in this class should determine the trajectory of the electron. I'm expecting a brief synopsis including several lines…not just a one or two word statement. **It's only two points…but if your work is detailed here I may give up to 2 *'s extra credit. If going for extra credit, do the work on a scratch paper page and tell me where to look…

Page intentionally left blank as scratch paper.