- *Print* your name and 9 digit Georgia Tech ID number *clearly* in the spaces below.
- You may use a calculator that cannot store letters, but no other aids or electronic devices.
- Free-response questions are numbered I–III. Show all your work clearly, including all steps and logic. Box your answer.
- Multiple-choice questions are numbered 1–7. For each, select the answer most nearly correct, circle this answer on your quiz, and bubble it on your answer sheet.
- Your score will be posted when your quiz has been graded. Quiz grades become final when the next is given.

- Be sure your writing is *dark*. Blue or black ink is recommended.
- Do not make any erasures in your free-response work. Cross out anything you do not want evaluated.
- Nothing written in the top margins will be evaluated.
- The standard formula sheet is on the back of this page. You may remove it from the quiz form if you wish, but it must be submitted.
- The answer sheet for multiple-choice questions is the last page of the quiz form. You may remove it from the quiz form if you wish, but don't forget to submit it.
- If the page for a free-response problem has insufficient space for your work, you may use the back of the answer sheet. Make a note on the problem page, so graders know where to find your work. This is the only extra sheet of work that can be evaluated.

Pages 9 and 10 had no questions

Quiz and Exam Formulæ & Constants

$$K = \frac{1}{4\pi\epsilon_0}$$
$$\Delta V = -\int \vec{E}\cdot d\vec{s}$$
$$V = K\frac{q}{r}$$
$$\Delta U = q\,\Delta V$$
$$I = dq/dt$$
$$P = I\,\Delta V$$
$$R = \frac{\Delta V}{I}$$

Series :

$$\frac{1}{C_{\text{eq}}} = \sum \frac{1}{C_i}$$
$$R_{\text{eq}} = \sum R_i$$

Parallel :

$$\frac{1}{R_{\text{eq}}} = \sum \frac{1}{R_i}$$
$$C_{\text{eq}} = \sum C_i$$

$$\vec{E} = K\frac{q}{r^2}\hat{r}$$
$$\vec{F} = K\frac{q_1 q_2}{r^2}\hat{r}$$
$$\vec{F} = q\vec{E}$$
$$\vec{p} = q\vec{d}$$
$$\vec{\tau} = \vec{p}\times\vec{E}$$
$$U = -\vec{p}\cdot\vec{E}$$
$$|\vec{E}| \propto \frac{|\vec{p}|}{r^3}$$
$$\Phi_{\text{E}} = \int \vec{E}\cdot d\vec{A}$$
$$\epsilon_0 \oint \vec{E}\cdot d\vec{A} = q_{\text{enclosed}}$$
$$\oint \vec{E}\cdot d\vec{\ell} = -\frac{d\Phi_{\text{B}}}{dt}$$
$$C = \frac{Q}{\Delta V}$$
$$C = \epsilon_0\frac{A}{d}$$
$$U = \tfrac{1}{2}C\,[\Delta V]^2$$
$$R = \rho\frac{\ell}{A}$$
$$\tau_{\text{C}} = RC$$
$$u_{\text{E}} = \tfrac{1}{2}\epsilon_0 E^2$$

$$\vec{B} = \frac{\mu_0 q}{4\pi}\,\frac{\vec{v}\times\hat{r}}{r^2}$$
$$d\vec{B} = \frac{\mu_0 I}{4\pi}\,\frac{d\vec{\ell}\times\hat{r}}{r^2}$$
$$\vec{F} = q\vec{v}\times\vec{B}$$
$$\vec{F} = I\vec{\ell}\times\vec{B}$$
$$\vec{\mu} = NI\vec{A}$$
$$\vec{\tau} = \vec{\mu}\times\vec{B}$$
$$U = -\vec{\mu}\cdot\vec{B}$$
$$\Phi_{\text{B}} = \int \vec{B}\cdot d\vec{A}$$
$$\oint \vec{B}\cdot d\vec{A} = 0$$
$$\oint \vec{B}\cdot d\vec{\ell} = \mu_0(I_{\text{c}} + I_{\text{d}})$$
$$L = \frac{\Phi_{\text{B}}}{I}$$
$$L = \mu_0 N^2\frac{A}{\ell}$$
$$U = \tfrac{1}{2}LI^2$$
$$B = \mu_0 n I$$
$$\tau_{\text{L}} = L/R$$
$$u_{\text{B}} = \frac{1}{2\mu_0}B^2$$

$$q = q_{\max}\left(1 - e^{-t/\tau_{\text{C}}}\right)$$
$$q = q_0 e^{-t/\tau_{\text{C}}}$$
$$I = I_{\max}\left(1 - e^{-t/\tau_{\text{L}}}\right)$$
$$I = I_0 e^{-t/\tau_{\text{L}}}$$
$$I = \int \vec{J}\cdot d\vec{A}$$
$$\vec{J} = \sigma\vec{E}$$
$$\mathcal{E} = -N\frac{d\Phi_{\text{B}}}{dt}$$
$$I_d = \epsilon_0\,\frac{d\Phi_{\text{E}}}{dt}$$
$$\mathcal{E} = -L\,\frac{dI}{dt}$$
$$c = f\lambda = \frac{|\vec{E}|}{|\vec{B}|}$$
$$\vec{S} = \frac{1}{\mu_0}\,\vec{E}\times\vec{B}$$

Fundamental Charge $e = 1.602\times10^{-19}\,\text{C}$
Earth's gravitational field $g = 9.81\,\text{N/kg}$
Coulomb constant $K = 8.988\times10^{9}\,\text{N}\cdot\text{m}^2/\text{C}^2$
Speed of Light $c = 2.998\times10^{8}\,\text{m/s}$

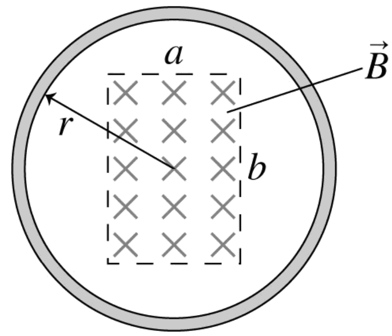
Mass of an Electron $m_{\text{e}} = 9.109\times10^{-31}\,\text{kg}$
Mass of a Proton $m_{\text{p}} = 1.673\times10^{-27}\,\text{kg}$
Vacuum Permittivity $\epsilon_0 = 8.854\times10^{-12}\,\text{C}^2/\text{N}\cdot\text{m}^2$
Vacuum Permeability $\mu_0 = 4\pi\times10^{-7}\,\text{T}\cdot\text{m/A}$

Unless otherwise directed, friction, drag, and gravity should be neglected, and all batteries and wires are ideal.
All derivatives and integrals in free-response problems must be evaluated. Problems about magnitudes will state so explicitly.

I. (16 points) A circular wire loop has radius r and resistance R. Within it, a rectangular region a wide and b high contains a magnetic field $\vec{B}$ directed into the page. The magnitude of this field depends on time t according to

$$B = B_0 \left(\frac{t}{t_0} \right)^2$$

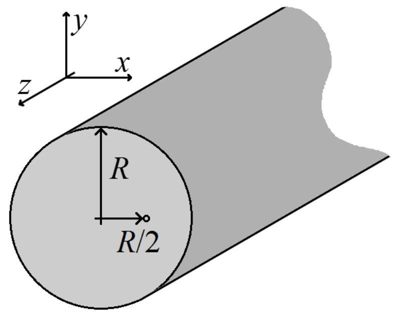
where B_0 and t_0 are positive constants. What is the current in the loop at time $t = T$? Express your answer in terms of parameters defined in the problem, and physical or mathematical constants.



II. (16 points) A cylindrical wire with radius R carries a current density $\vec{J}$ that depends on distance r from the cylinder axis according to

$$\vec{J} = J_0 \frac{r}{R} \hat{k}$$

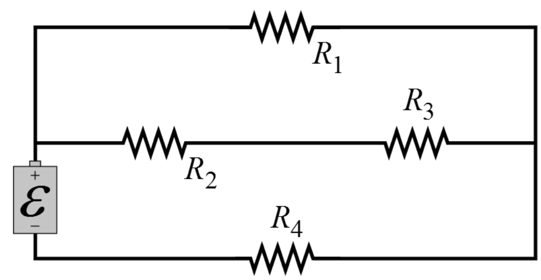
where J_0 is a positive constant. What is the magnitude of the magnetic field at a distance $R/2$ from the center of the wire? Express your answer in terms of parameters defined in the problem, and physical or mathematical constants.



1. (6 points) In the problem above, what is the direction of the magnetic field at the indicated point right of the wire's center?
   (a) In the $+x$ direction.
   (b) In the $-y$ direction
   (c) In the $+z$ direction.
   (d) In the $+y$ direction
   (e) In the $-x$ direction.

III. (16 points) The circuit shown is constructed with a 12 V battery, and four resistors having resistances

$R_1 = 32\,\Omega$
$R_2 = 14\,\Omega$
$R_1 = 18\,\Omega$
$R_1 = 8.0\,\Omega$



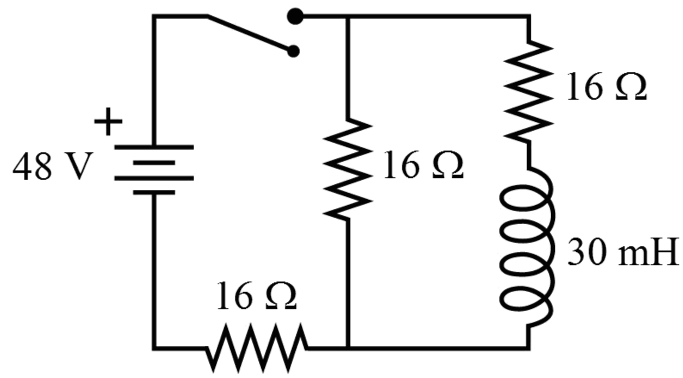
What is the power dissipated in resistor R_1?

2. (6 points) In the problem above, let power dissipated in resistor R_1 be P_1. If a different battery were used in the circuit, with a potential difference twice that of the battery above (that is, $\mathcal{E}' = 2\mathcal{E}$), what would be the resulting power P_1' dissipated in resistor R_1?

(a) $P_1' = P_1/4$
(b) $P_1' = P_1$
(c) $P_1' = 2P_1$
(d) $P_1' = P_1/2$
(e) $P_1' = 4P_1$

3. (8 points) A circuit is constructed with a 48 V battery, a switch, three 16 Ω resistors, and a 30 mH inductor, as shown. The switch has been open for a long time. What current is supplied by the battery immediately upon closing the switch?

(a) 9.0 A
(b) 1.5 A
(c) 1.0 A
(d) 2.0 A
(e) 4.0 A



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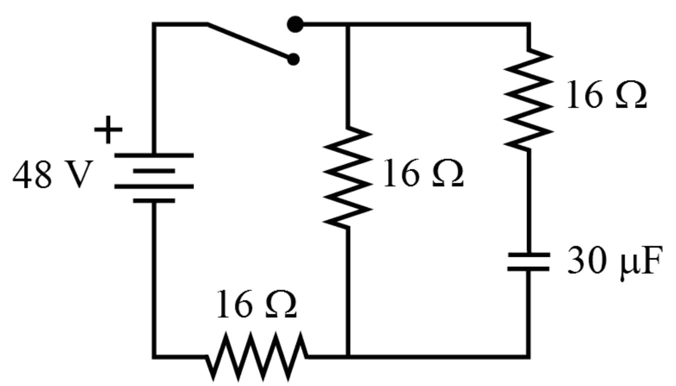
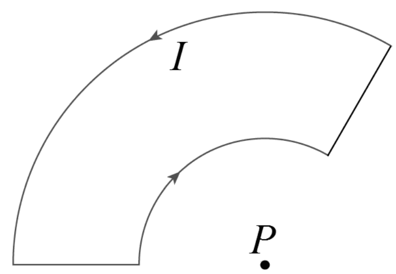
4. (8 points) A circuit is constructed with a 48 V battery, a switch, three 16 Ω resistors, and a 30 μF capacitor, as shown. The switch has been open for a long time. What current is supplied by the battery immediately upon closing the switch?

(a) 1.5 A
(b) 4.0 A
(c) 1.0 A
(d) 9.0 A
(e) 2.0 A



5. (8 points) Current flows counter-clockwise around a wire loop that is formed from two concentric circular arcs, connected by radii, as shown. What is the direction, if any, of the magnetic field at point P, which lies at the center of the two arcs?

   (a) Directly toward the arcs, up the page and to the left.
   (b) In to the page.
   (c) No direction, as magnitude is zero.
   (d) Directly away from the arcs, down the page and to the right.
   (e) Out of the page.



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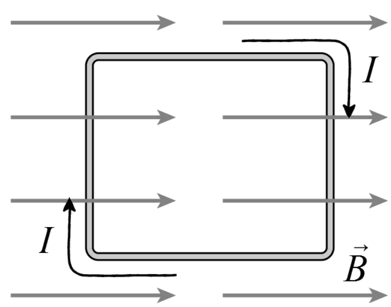
6. (8 points) A rectangular wire loop lies in the plane of the page with clockwise current I. A uniform magnetic field $\vec{B}$ is directed to the right, as shown. If there is a *net* torque on the loop, which side of the loop will tend to be lifted out of the page toward you?

   (a) A net torque will lift the *lower* side out of the page.
   (b) A net torque will lift the *right* side out of the page.
   (c) There is no *net* torque.
   (d) A net torque will lift the *upper* side out of the page.
   (e) A net torque will lift the *left* side out of the page.



7. (8 points) The plates in a capacitor have a potential difference of 2 kV between them. A particle of unstated charge is released from rest at the +2 kV plate and accelerates toward the 0 V plate. It passes through a small hole and enters a uniform magnetic field. If the particle's path is deflected up the page as shown, what is the direction of the magnetic field?

(a) To the right.
(b) Out of the page.
(c) Up the page.
(d) Down the page.
(e) Into the page.