Formulas:

$F = k\frac{q_1 q_2}{r^2}$ Coulomb's law ; $k = \frac{1}{4\pi\varepsilon_0} = 8.99\times10^9 \mathrm{N\cdot m^2/C^2}$; $\varepsilon_0 = 8.85\times10^{-12} C^2/Nm^2$

Electric field: $\vec{E} = \frac{q}{4\pi\varepsilon_0 r^2}\hat{r} = \frac{kq}{r^2}\hat{r}$; $\vec{E}(\vec{r}) = k\int \rho(\vec{r}\,')\frac{\vec{r}-\vec{r}\,'}{|\vec{r}-\vec{r}\,'|^3}d^3r'$; $\vec{F} = q_0\vec{E}$

Linear, surface, volume charge density: $dq = \lambda\, d\ell$, $dq = \sigma\, da$, $dq = \rho\, dv$

Electric field of infinite: line of charge: $E = \frac{\lambda}{2\pi\varepsilon_0 r}$; sheet of charge: $E = \frac{\sigma}{2\varepsilon_0}$

$\vec{\nabla}\times\vec{E} = 0$ (electrostatics)

Gauss law: $\Phi = \oint \vec{E}\cdot d\vec{a} = \frac{q_{enc}}{\varepsilon_0} = \frac{1}{\varepsilon_0}\int d^3r\, \rho(\mathrm{r})$; Φ=electric flux

Energy: $U = k\frac{q_1 q_2}{r_{12}}$ $U = \frac{\varepsilon_0}{2}\int E(\vec{r})^2 d^3r$ Work: $W = \int \vec{F}\cdot d\vec{s}$

Electric potential: $\phi(P_2) - \phi(P_1) = -\int_{P_1}^{P_2} \vec{E}\cdot d\vec{s}$ $\phi(\vec{r}) = \frac{1}{4\pi\varepsilon_0}\int d^3r' \frac{\rho(\vec{r}\,')}{|\vec{r}-\vec{r}\,'|}$

Point charge: $\phi(\vec{r}) = \frac{1}{4\pi\varepsilon_0}\frac{q}{r}$ Dipole: $\phi(r,\theta) = \frac{p\cos\theta}{4\pi\varepsilon_0 r^2}$

$U = \frac{1}{2}\int \rho\, \phi\, d^3r$ $\vec{\mathrm{E}} = -\vec{\nabla}\phi$; $\vec{\nabla}\cdot\vec{E} = \frac{\rho}{\varepsilon_0}$; $\vec{\nabla}\times\vec{E} = 0$

Capacitors: $Q = C\phi$, $U = \frac{Q^2}{2C}$; Planar: $C = \frac{\varepsilon_0 A}{s}$ Spherical: $C = 4\pi\varepsilon_0 R$

$I = \int \vec{J}\cdot d\vec{a}$, $I = \frac{dQ}{dt}$, $\vec{J} = nq\vec{u}$; $div\vec{J} = -\frac{\partial\rho}{\partial t}$; Power: $P = I^2R$; $P = \varepsilon I$

V=IR; $\vec{J} = \sigma\vec{E}$; $\vec{E} = \rho\vec{J}$; $R = \rho\frac{L}{A}$; $\sigma = \frac{ne^2\tau}{m_e}$; $Q(t) = C\varepsilon(1-e^{-t/RC})$; $Q(t) = Q_0 e^{-t/RC}$

Lorentz force: $\vec{F} = q(\vec{E}+\vec{v}\times\vec{B})$; force on wire: $d\vec{F} = Id\vec{\ell}\times\vec{B}$; solenoid: $B = \mu_0 nI$

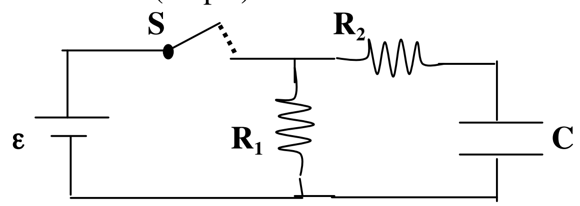
Stokes' theorem: $\oint_C \vec{F}\cdot d\vec{s} = \int_S (\vec{\nabla}\times\vec{F})\cdot d\vec{a}$; vector potential: $\vec{\nabla}\times\vec{A} = \vec{B}$

Ampere's law: $\oint_C \vec{B}\cdot d\vec{s} = \mu_0 I_{enc} = \mu_0\int_S \vec{J}\cdot d\vec{a}$; $\vec{\nabla}\times\vec{B} = \mu_0\vec{J}$; $\vec{\nabla}\cdot\vec{B} = 0$

Field of a wire: $B = \frac{\mu_0 I}{2\pi r}\hat{\theta}$; Force between wires: $F = \frac{\mu_0 I_1 I_2 \ell}{2\pi r}$; cyclotron: $\omega = \frac{qB}{m}$

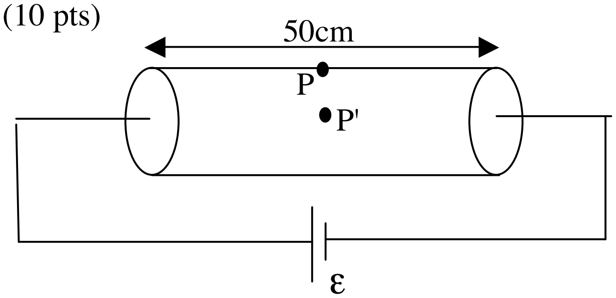
$\mu_0 = 4\pi\times10^{-7} kg\ m/C^2$

Problem 1 (10 pts)



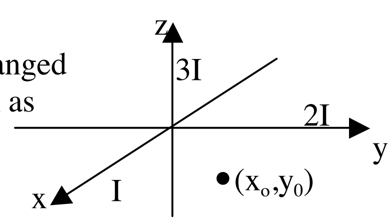
In the circuit in the figure, the two resistors shown have the same value, $R_1=R_2=R$. Initially the charge in the capacitor C is zero and the switch S is open. Then the switch is closed, and a current 1A circulates through R_1 immediately after the switch is closed.
(a) A long time thereafter, how much current will circulate through R_1?
(b) Assume at that time (i.e. a long time after S was closed), S is opened again. How much current will circulate through R_1 right after S is opened again?
(c) How long after S is opened again will the power dissipated in R_1 be ½ as large as immediately after S is opened again? Give your answer in terms of $t_0=RC$.

Problem 2 (10 pts)



The cylindrical conductor shown in the figure has length 50cm, cross-sectional area 1mm^2 and is made of Cu, with resistivity $1.7\text{x}10^{-8}$ ohm-meter. The emf ε=0.2V. Assume the other wires in the circuit have zero resistance.
(a) Find the current flowing through the cylinder, in A (amperes).
(b) Find the magnitude of the magnetic field at point P at the surface of the cylinder, in T.
(c) Find the magnitude of the electric field (in N/C) and of the magnetic field (in T) at point P' on the axis of the cylinder.

Problem 3 (10 pts)



Consider 3 wires with currents I, 2I and 3I respectively arranged along the x, y and z axis of a rectangular coordinate system as shown in the figure.
(a) Find the magnetic field at a point (x_0,y_0) in the xy plane. You can give your result either in Cartesian coordinates, B_x, B_y, B_z or in cylindrical coordinates B_r, B_θ, B_z. Give also the magnitude of B.
(b) Find the line integral $\oint_C \vec{B}\cdot d\vec{s}$ where C is a rectangle in the (x,y) plane with vertices at points $(\pm x_0, \pm y_0)$.