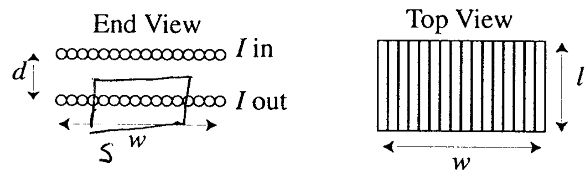
Name Solutions

Exam #3
Physics 248
April 26, 2001

Each problem is worth 25 points

Problem	Score
1	
2	
3	
4	
Total	

1. Shown below is a "parallel-plate" inductor, consisting of two sets of N wires, each wire carrying current I. For the top plate, the currents flow into the page, while for the bottom plate the currents flow out of the page. The width of the plates is w, the length l, and the distance between them $d \ll w, l$.



(a) Use Ampere's law to find the magnetic field (magnitude and direction) in between the two plates. You may assume the field is zero everywhere except between the plates.

$\leftarrow B$

$$B S = \mu_0 I \frac{N S}{W} \Rightarrow B = \mu_0 \frac{N I}{W}$$

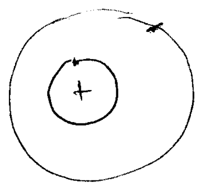
(b) Calculate the magnetic energy.

$$U = \int dV \frac{B^2}{2\mu_0} = \frac{\mu_0^2 N^2 I^2}{2\mu_0 W^2} \cdot lwd = \mu_0 \frac{N^2 I^2}{2} \frac{ld}{W}$$

(c) Calculate the inductance.

$$U = \frac{1}{2} L I^2 \Rightarrow L = \mu_0 N^2 \frac{ld}{W}$$

2. We showed how the famous Bohr formula works for hydrogenlike atoms and, with corrections, for X-Ray spectra involving inner electron shells. It also works well for the energy levels of the outermost electron of any atom very near the ionization limit. Calculate the frequency of light emitted by a Rb atom in moving from the $n = 51$ level to the $n = 50$ level.

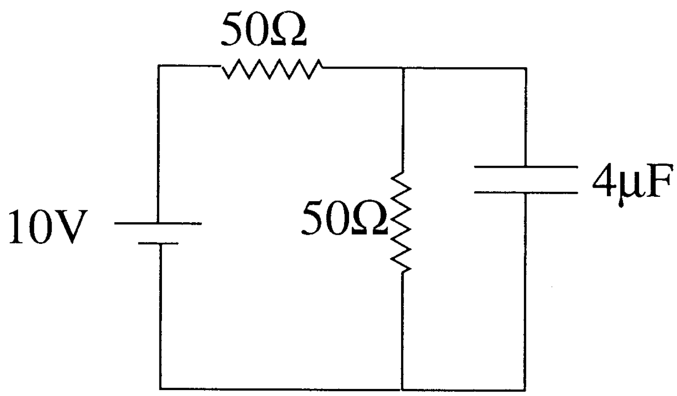


$$h\nu = 13.6\,\text{eV}\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$

$$\nu = \frac{13.6\,\text{eV} \cdot 3\times10^{18}\,\text{Å/s}}{12400\,\text{eVÅ}}\left(\frac{1}{50^2} - \frac{1}{51^2}\right)$$

$$= 51\,\text{GHz}$$

3. An RC circuit is shown below.

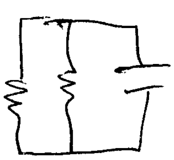


(a) When the capacitor is fully charged, find the amount of stored charge and the current through each resistor. ↘ $I = 0$ through C

$$Q = CV = 4\mu F \times 5V = 2 \times 10^{-5} C$$

$$I = \frac{10V}{100\Omega} = 0.1A$$ through each resistor

(b) The battery is suddenly removed and replaced by a wire. Find the voltage across the capacitor as a function of time.



R's in parallel, 25 Ω, $RC = 25\Omega \cdot 4 \times 10^{-6} F = 10^{-4}$ sec

$$V = 5V\, e^{-\frac{t}{10^{-4} s}}$$

4. A planar circuit of area A lying in the x-z plane carries a current $I(t) = I_0 \cos(2\pi\nu t)$. A distance y far, far away on the y-axis is a second circuit of area a, tipped at angle θ as shown. Find the voltage induced in the second circuit, and the mutual inductance of the two circuits.

Field from dipole $B = \frac{\mu_0}{4\pi} \cdot \frac{2\mu}{y^3}$ $\qquad \mu = IA$

$$\phi = Ba\cos\theta$$

$$= \frac{\mu_0}{4\pi} \cdot \frac{2 I_0 A}{y^3} \cdot a \cos\theta \cos(2\pi\nu t)$$

$$-\frac{d\phi}{dt} = \mathcal{E} = \frac{\mu_0}{2\pi} \frac{I_0 A}{y^3} a\cos\theta \, 2\pi\nu \sin 2\pi\nu t$$

$$= \mu_0 I_0 \frac{Aa}{y^3} \cos\theta\, \nu \sin 2\pi\nu t$$

$$\phi = MI = \frac{\mu_0}{4\pi} \cdot 2 \frac{A}{y^3} a\cos\theta \, I$$

$$M = \frac{\mu_0}{2\pi} \frac{Aa\cos\theta}{y^3}$$