Assignment #6 Physics 346

Solutions

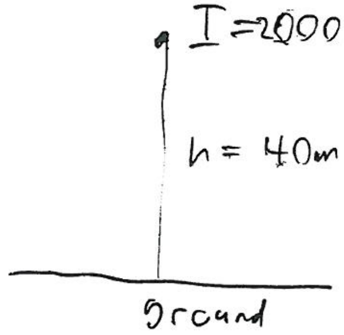
Due 4:30 pm **Friday** March 9, 2012

Use Phys 346 drop box located at entrance to Physics Dept. off main floor of AQ.

1. This question explores the magnetic field generated by high voltage transmisssion lines
   (a) A single transmission line is 40 m above the surface of the earth and carries 2000A of current. What is the peak magnetic field at ground level directly under the wire?
   (b) Suppose now that we have a two wire system in which the currents are opposite in direction at the same height. Assume that the maximum current from part (a) is flowing in each wire. Suppose the wires are separated horizontally by 4 m. What is the magnetic field at a point on the surface of the earth, directly under the midpoint between the two wires? Note that you will have to use vectors for this part. You only need to focus on the y components (why?).
2. A fluourescent lamp consists of a glass insulating tube with two electrodes 1 m apart. It is mounted vertically below a 250 kV power line with one end embedded in the ground (ground end is at zero volts). It takes $\sim$ 1 kV across the electrodes to start it. If the power line is 50m high, does the lamp light up?
3. A home owner who lives beside a 60 Hz power line decides to "harvest" some energy from the oscillating field. The person constructs a 100 turn coil with area 1m^2 and places it directly under the power line (for simplicity assume a single wire line).
   (a) How should they orient the coil for maximum output?
   (b) If the power line has a height of 40m and a current of 2000A, what is the peak induced voltage in the coil?
4. Your laptop WiFi transmits at 900MHz.
   (a) Calculate the wavelenth of the EM waves
   (b) Calculate the energy for a single photon for this freqency. Is this significant in terms of biological damage and why?
5. Questions from your text:
   Ch 8 Problems # 9, 13, 14, 15

Assignment #6

1. (a)

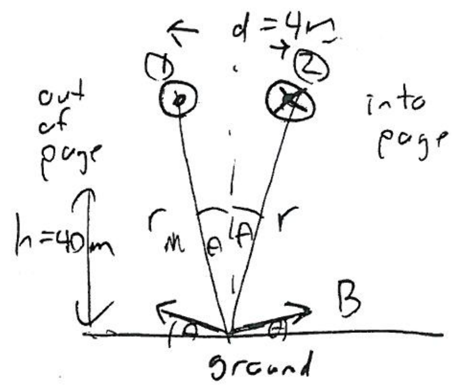


$$B = \frac{\mu_0 I}{2\pi r} = \frac{(4\pi \times 10^{-7})(2000A)}{2\pi(40)}$$

$$= 1 \times 10^{-5}\ T$$

$$= \underline{100\ mG}$$

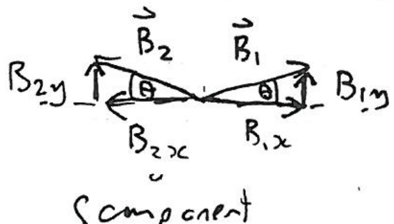
(b)



x components cancel by symmetry

total y components:

$$2B_y = 2\frac{\mu_0 I}{2\pi r}\sin\theta$$



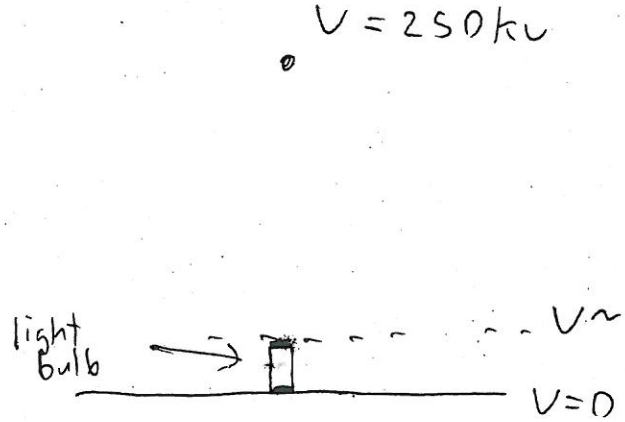
$$\sin\theta = \frac{d/2}{r}$$

$$\therefore 2B_y = \frac{(2)(4\pi \times 10^{-7}) \times (2000A)(2)}{2\pi(2^2 + 40^2)}$$

$$= 9.98 \times 10^{-7}\ T = 9.98\ mG$$

much smaller.

(2)



Electric field gradient

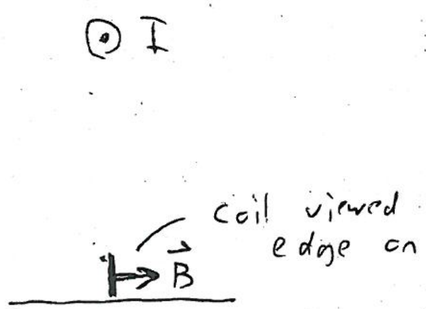
$E \sim \frac{\Delta V}{\Delta x} \sim \frac{250 kV}{50 m}$

$= 5 \frac{kV}{m}$

This means the 1 m above the ground, the voltage is ~ 5kV
This should be enough to start the bulb

(3) (a) Since the magnetic field is horizontal at ground level, they should orient the coil with its axis horizontal (plane of coil is aligned vertical)

(b)



From question (2) $B \sim 10^{-5} T$ at ground level

Because the current is oscillating, so is B
ie $B = B_0 \cos 2\pi f t$

$$|\mathcal{E}| = N \left| \frac{d\Phi}{dt} \right| = N B_0 (2\pi f) \sin(2\pi f t) A$$
$$= (100)(10^{-5} T)(2\pi\, 60 s^{-1})(1 m^2)$$
$$= 0.38 V \quad \text{(not very useful)}$$

④ $f = 900\,MHz$

(a) $c = \frac{\lambda}{T} = \lambda f$

$\therefore \lambda = \frac{c}{f} = \frac{3 \times 10^8 \, m/s}{9 \times 10^8 \, Hz}$

$\lambda = \underline{0.33\,m}$

(b) $E = hf = \frac{(6.626 \times 10^{-34} \, J\,s)(9.0 \times 10^8 \, s^{-1})}{1.602 \times 10^{-19} \, J/eV}$

$= 3.72 \times 10^{-6} \, eV$

This is much too small to cause direct chemical bond breakage, hence any biological effect would primarily be limited to heating effects
(Because of the low power of WIFI this should be negligible)

8 - 9

$V_1 = 120\,V$
$V_2 = 6.3\,V$

$\frac{V_1}{V_2} = \frac{N_1}{N_2}$

$\therefore \frac{120V}{6.3V} = \frac{400}{N_2} \quad \therefore N_2 = \frac{400(6.3)}{(120)}$

$\therefore N_2 = 21$ turns

Problem 8-13. Calculat the peak value of the voltage induced in a generator where $N = 20$ # turns

$A = 0.04\,m^2$ area.

$f = 60$ rev/s.

$B = 1.0T$.

$\therefore V_p = \omega NAB$

$= 60\,rev/s \cdot 2\pi\,rad/rev \cdot 20 \cdot 0.04m^2 \cdot 1T$

$= 301V$

What power is dissipated across a 100Ω resistor?

$P = \frac{V^2}{R} = \frac{V_p^2}{2R} = \frac{(301)^2 V^2}{2 \cdot 100\Omega} = 454\,W.$

8-14

$\circlearrowleft \omega$ angular frequency

$N = 828$

$\Phi = BL^2 \cos 2\pi f t$

$f = 3600 \text{ rpm} = 60 \text{ Hz}$

(a) $V = \left| N \frac{d\Phi}{dt} \right| = NBL^2 2\pi f \sin(2\pi f t)$

$V_p = NBL^2 2\pi f$

$P_p = \frac{V_p^2}{R} = \frac{NBL^2 2\pi f}{R} = \frac{(828)(0.2T)(.05m)^2(2\pi 60s^{-1})}{55\,\Omega}$

$= \underline{\underline{442}}\ W$

(b) $V_{rms} = \frac{V_p}{\sqrt{2}} = \frac{NBL^2 2\pi f}{\sqrt{2}} = \frac{(828)(0.2T)(.05)^2(2\pi 60s^{-1})}{\sqrt{2}}$

$= 110V$

$I_{rms} = \frac{V_{rms}}{R} = \frac{110V}{55\,\Omega} = \underline{2.00A}$

$P_{ower} = I_{rms} V_{rms} = (2.00A)(110V)$

$= \underline{\underline{220}}\ W$

Problem. 8-15. Find the current flowing in the secondary coil of a neighbourhood transformer.

$V_1 = 44\,kV$ $\qquad I_1 = 5.5A$.

$V_2 = 120V$.

for constant power, $V_1 I_1 = V_2 I_2$

$$\therefore I_2 = \frac{V_1}{V_2} \cdot I_1$$

$$= \frac{44\,kV}{120V} \cdot 5.5A$$

$$\therefore I_2 = 2.0 \times 10^3\ A.$$