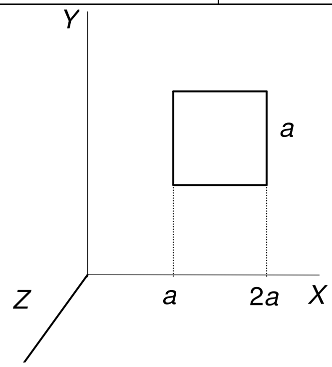
UNIVERSIDAD POLITECNICA DE VALENCIA	Third mid term exam FFI **January 14th 2019** Year 2018/19	Applied Physics Dept.

1. (2,5 points) A squared loop with side ***a*** and resistance ***R*** is placed inside a **uniform** and not stationary magnetic field $\mathbf{B}=(3t+2)\mathbf{k}\ T$ (t is the time in seconds). Find: a) Magnetic flux ϕ through the loop, as a function of t. b) Induced electromotive force **ε** on the loop. c) Intensity of current **i** flowing along the loop, giving its direction. d) Force ***F*** (in vector form) acting on the upper side of the loop when **t=2 s**. e) Explain (calculations are not needed) if the total force acting on the whole loop should be null (or not).	**1.** (2,5 puntos) Una espira cuadrada de lado ***a*** y resistencia ***R*** se encuentra dentro de un campo magnético uniforme y no estacionario $\mathbf{B}=(3t+2)\mathbf{k}\ T$ (t es el tiempo en segundos). Calcula: a) Flujo magnético ϕ que atraviesa la espira en función de t. b) Fuerza electromotriz **ε** inducida en la espira. c) Intensidad de corriente **i** que circula por la espira, indicando su sentido. d) Fuerza ***F*** (en forma vectorial) que actúa sobre el lado superior de la espira en el instante t=2 s. e) Razona (sin hacer los cálculos) si la fuerza total que actúa sobre la espira completa debe ser nula, o no.



Solution

a) As magnetic field is uniform and parallel to surface vector: $\phi=\int_S B\cdot dS=\int_S B\cdot dS=B\int_S dS=BS=(3t+2)a^2$

b) $\varepsilon=\frac{d\varphi}{dt}=3a^2$

c) $i=\frac{\varepsilon}{R}=\frac{3a^2}{R}$ The magnetic field is exiting from the paper, and then the exiting flux is increasing on time. Therefore, the induced current must create a magnetic field (and a flux) entering on paper. To do it, the induced current must be clockwise.

d) $B(t=2)=(3\cdot 2+2)k=8k\ T$

As magnetic field is uniform: $F(t=2)=i\left(L\times B(t=2)\right)=\frac{3a^2}{R}\begin{vmatrix} i & j & k \\ a & 0 & 0 \\ 0 & 0 & 8 \end{vmatrix}=\frac{24a^3}{R}(-j)$

e) The total force acting on the whole loop will be null because the force acting on a loop inside a magnetic field is zero if the magnetic field is uniform. As $\boldsymbol{B}$ is uniform, then the total force acting on the loop will be null.

2. (2,5 points) Let's consider a coil having ***50 cm*** length, ***3000 turns*** and radius ***20 cm***, flowed by an intensity of current ***2 A***. A second coil with the same length, ***400 turns***, and radius ***5 cm*** is coaxially placed inside the first one. Compute: a) The magnetic field produced by the first coil at a point of its axis. b) The flux through the second coil produced by the first one. c) The mutual inductance coefficient between both coils. d) If the current along first coil is varying on time according **i(t)=2cos(100t)**, compute the absolute value of the electromotive force induced on the second coil.	**2.** (2,5 puntos) Sea un solenoide de ***50 cm*** de longitud, ***3000 espiras***, y ***20 cm*** de radio, por el que circula una corriente de ***2 A***. Un segundo solenoide de la misma longitud, ***400 espiras*** y ***5 cm*** de radio está situado coaxialmente dentro del primero. Calcular: a) El campo magnético producido por el primer solenoide en un punto de su eje. b) El flujo que el primer solenoide produce sobre el segundo. c) El coeficiente de inducción mutua entre ambos solenoides. d) Si la corriente en el primer solenoide varía con el tiempo según la expresión **i(t)=2cos(100t)**, calcula el valor absoluto de la f.e.m. inducida en el segundo solenoide.

Solution

a) By considering the magnetic field uniform inside the coil $B=\mu_0\frac{3000}{50\cdot10^{-2}}2=12\mu_0 10^3=48\pi10^{-4}\ T$

b) $\phi=BNS=12\mu_0 10^3 400\pi(5\cdot10^{-2})^2=12\mu_0\pi10^3=48\pi^2 10^{-4}Wb$

c) $M=\frac{\phi}{I}=\frac{12\mu_0\pi10^3}{2}=6\mu_0\pi10^3=24\pi^2 10^{-4}H$

d) $|\varepsilon_2|=\left|\frac{d\phi_2}{dt}\right|=\left|\frac{d(Mi)}{dt}\right|=\left|M\frac{di}{dt}\right|=\left|24\pi^2 10^{-4}(100\cdot2\cdot sen(100t))\right|=\left|48\pi^2 10^{-2}sen(100t)\right|V$

3. (2,5 points) A capacitor ***2,5 mF*** sized and a ***3 Ω*** resistor are connected in series (dipole RC). Along the RC dipole flows a current ***i(t)=5cos(100t-10º)*** A. Find: a) The instantaneous voltage on resistor, u_R(t). b) The instantaneous voltage on capacitor, u_C(t). c) The impedance, Z, and the phase lag of dipole, φ. Draw the impedance triangle. d) The instantaneous voltage on terminals of RC dipole, u(t). e) Compute the self-inductance coefficient, L, of the inductor should be added in series to R and C in order the new circuit was in resonance (at the given angular speed).	**3**. (2,5 puntos) Un condensador de ***2,5 mF*** y una resistencia de ***3 Ω*** están conectados en serie (dipolo RC). Por el dipolo RC circula una corriente ***i(t)=5cos(100t-10º)*** A. Calcula: a) La tensión instantánea en la resistencia, u_R(t). b) La tensión instantánea en el condensador, u_C(t). c) La impedancia, Z, y el ángulo de desfase del dipolo, φ. Dibuja el triángulo de impedancias. d) La tensión instantánea en los terminales del dipolo RC, u(t). e) Calcula el coeficiente de autoinducción, L, que debería tener una autoinducción añadida en serie con R y C, de tal manera que el nuevo circuito esté en resonancia (con la pulsación dada).

Solution:

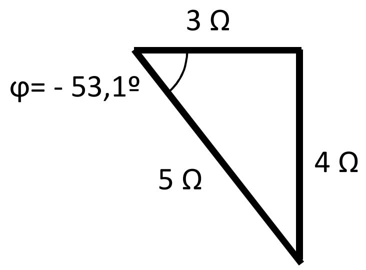
a) $u_R(t)=3\cdot5\cos(100t-10º)=15\cos(100t-10º)\,V$

b) $X_C=\frac{1}{C\omega}=\frac{1}{2,5\cdot10^{-3}\cdot100}=4\,\Omega$ $\qquad -90=\varphi_u-(-10)\Rightarrow\varphi_u=-90-10=-100º$

$$u_C(t)=4\cdot5\cos(100t-100º)=20\cos(100t-100º)\,V$$

c) $Z=\sqrt{R^2+(1/c\omega)^2}=\sqrt{3^2+4^2}=5\,\Omega$ $\qquad tg\varphi=\frac{-X_C}{R}=\frac{-4}{3}=-1,33\Rightarrow\varphi=-53,1º=-0,93rad$

The impedance triangle is:



d) $-53,1=\varphi_u-(-10)\Rightarrow \varphi_u=-53,1-10=-63,1º$ $\quad U_m=I_m Z=5\cdot 5=25\,V$

$$u(t)=25\cos(100t-63,1º)\,V$$

e) A RLC circuit is in resonance when $X_L=X_C$. As $X_C=4\ \Omega$, must be verified:

$$X_L=L\omega=X_C\Rightarrow L\cdot 100=4\Rightarrow L=\frac{4}{100}=0,04\,H=40\,mH$$

4. (2,5 points) On circuit on picture every diodes have drop forward voltage ***V_u=0,7 V***, and internal resistance negligible (also the battery).

a) On a table like the next one, mark with a cross the correct bias (forward or reverse) for every diode:

Diode	Forward	Reverse
D_1		
D_2		
D_3		

b) Compute intensities I_1, I_2 and I_3 flowing along diodes D_1, D_2 and D_3.

c) Compute the differences of potential V_A-V_C and V_C-V_B.

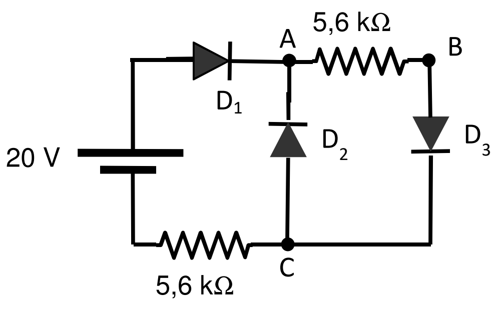
4. (2,5 puntos) En el circuito de la figura, todos los diodos tienen tensión umbral ***V_u=0,7 V***, y resistencia interna despreciable (también el generador).

a) En una tabla como la siguiente, marca con una cruz la correcta polarización de cada diodo:

Diodo	Directa	Inversa
D_1		
D_2		
D_3		

b) Calcula las intensidades I_1, I_2 e I_3 que circulan por los diodos D_1, D_2 y D_3.

c) Calcula las diferencias de potencial V_A-V_C y V_C-V_B.



Solution:

a)

Diode	Forward	Reverse
D_1	X	
D_2		X
D_3	X	

b) $I_1 = I_3 = \dfrac{20-0,7-0,7}{5,6+5,6} = 1,66\ mA \qquad I_2 = 0$

c) As D_2 is reverse biased $V_A - V_C = I_3 \cdot 5,6 + 0,7 = 1,66 \cdot 5,6 + 0,7 = 10\,V$

On the other hand, as D_3 is forward biased, $V_C - V_B = -0,7\,V$

FORM

Magnetic Forces $F = q(v \times B)$ $\quad dF = Idl \times B$ $\quad \mu = N \cdot I \cdot S$ $\quad \tau = \mu \times B$ $\quad V_H = \dfrac{I \cdot B \cdot d}{n \cdot e \cdot S}$

Sources of magnetic field $dB = \dfrac{\mu_0 I}{4\pi}\dfrac{d \quad \times r}{r^3}$ $\quad \mu_0 = 4\pi 10^{-7}$ (I.S.units) $\quad B = \dfrac{\mu_0 I}{2\pi x}$

$B = \dfrac{\mu_0 I}{2R}$ $\quad \int_L B \cdot dl = \mu_0 \sum I$ $\quad B = \dfrac{\mu_0 NI}{l}$

Electromagnetic induction $|\varepsilon| = \dfrac{d\phi}{dt}$ $\quad \phi = L \cdot I$ $\quad \phi_{21} = M \cdot I_1$ $\quad W_L = \dfrac{1}{2} L \cdot I^2$

Alternating current $\varphi = \varphi_u - \varphi_i$ $\quad X_L = L\omega$ $\quad X_C = \dfrac{1}{C\omega}$ $\quad U_{rms} = \dfrac{U_m}{\sqrt{2}}$ $\quad I_{rms} = \dfrac{I_m}{\sqrt{2}}$

$tg\varphi = \dfrac{L\omega - 1/C\omega}{R}$ $\qquad Z = \dfrac{U_m}{I_m} = \sqrt{R^2 + \left(L\omega - 1/c\omega\right)^2}$

$P(t) = u(t) \cdot i(t) = U_m I_m \cos\varphi \sin^2 \omega t + \dfrac{U_m I_m}{2} \sin\varphi \sin 2\omega t$ $\qquad P = U_{rms} I_{rms} \cos\varphi$ $\qquad f_0 = \dfrac{1}{2\pi}\sqrt{\dfrac{1}{LC}}$

Semiconductors $n \cdot p = n_i^2$ $\qquad N_A + n = N_D + p$