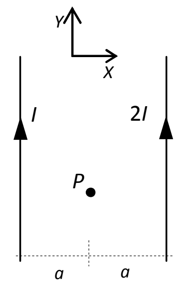
UNIVERSIDAD POLITECNICA DE VALENCIA

Second modular exam FFI
January 15th 2014
Year 2013/14

Applied Physics Dept.

1. Picture shows two straight carrying current conductors (distance **2a** among them) flowed by intensities I_1=**I** and I_2=**2I**. Point **P** is placed in the middle among both wires.
a) (1) Compute the magnetic field on P due to both conductors. Result must be given as a vector, according the shown reference system.
b) (1) There is a **positive** charge **q** on point P moving with a velocity $\vec{\mathbf{v}} = 2\vec{\mathbf{i}}\ \mathbf{m/s}$. Compute the acting force on charge at this time. Give the result as a vector.
2 points

1. La figura muestra dos conductores rectilíneos separados una distancia **2a** y recorridos por sendas intensidades **I** y **2I**. El punto **P** se encuentra a la misma distancia de ambos conductores.
a) (1) Calcular el campo magnético resultante en P. Dar el resultado en forma vectorial, de acuerdo con el sistema de referencia mostrado.
b) (1) En el punto P se encuentra una carga **q** **positiva** que se mueve con velocidad $\vec{\mathbf{v}} = 2\vec{\mathbf{i}}\ \mathbf{m/s}$. Calcular la fuerza que actúa sobre dicha carga en ese instante. Dar el resultado como un vector.
2 puntos



a) Magnetic field on P is the addition of magnetic fields due to both conductors on P; as both magnetic fields have opposite senses:

$$\vec{B}_1 = \frac{\mu_0 I}{2\pi a}(-\vec{k})\,T \qquad \vec{B}_2 = \frac{\mu_0 2I}{2\pi a}(\vec{k})\,T \qquad \vec{B} = \vec{B}_1 + \vec{B}_2 = \frac{\mu_0 I}{2\pi a}\vec{k}\,T$$

b) The force acting on a moving charge inside a magnetic field is: $\vec{F} = q(\vec{v}\times\vec{B}) = q(2\vec{i}\times\frac{\mu_0 I}{2\pi a}\vec{k}) = -\frac{\mu_0 I q}{\pi a}\vec{j}\ N$

2. State Ampère’s law and apply it to compute the magnetic field created by an infinite straight carrying current wire, flowed by an intensity of current **I**, on a point placed at a distance **x** from wire. Explain the computations done.
1 point

2. Enuncia el teorema de Ampère y aplícalo para calcular el campo magnético creado por un conductor rectilíneo e indefinido, recorrido por una intensidad de corriente **I**, en un punto situado a una distancia **x** del conductor. Explica los cálculos realizados.
1 punto

Ampére’s law statement appears on point 7.5 of notes:
“The circulation of magnetic field vector along any enclosed curve equals the product of the constant μ0 by the addition of the intensities of current crossing any surface bordered by the curve. The sign of the intensity will be positive when it was in accordance with the screw or the right hand rule with the sense of the circulation, and negative in another case.”

$$C = \oint \vec{B}\,d\vec{l} = \mu_0 \sum I$$

Related to the magnetic field created by a straight carrying current wire, on a point placed at a distance x, appears on next page:

In order to apply Ampère’s law, we choose a circumference of radius *x*, perpendicular to conductor and centered on a point of such conductor. This circumference is a field line of magnetic field, being the magnetic field vector tangent to this line at any point. On the other hand, as distance to conductor is the same for all the points of line, modulus of magnetic field will also be the same. So, circulation of magnetic field along this circumference is $C = \oint \vec{B}\,d\vec{l} = B2\pi x$

Considering the surface of a disk bordered by this circumference, the intensity crossing this disk is *I* (positive because its sense is in accordance with the sense of circulation chosen). Then, applying Ampère’s law becomes

$$C = \oint \vec{B}\,d\vec{l} = B2\pi x = \mu_0 I \Rightarrow B = \frac{\mu_0 I}{2\pi x}$$

3. A squared loop with side **a** and electrical resistance **R** is placed inside a uniform magnetic field, varying on time according $\mathbf{B=B_0 t}$ T, perpendicular to the loop ($\mathbf{B_0}$ is a positive constant and **t** is the time). Compute:

a) (1) Flux of magnetic field through the loop as a function of **t**.

b) (0,5) Electromotive induced force on loop.

c) (0,5) Induced current flowing along the loop, clearly giving its sense (clockwise or counterclockwise), reasoning the answer.

d) (0,5) The force acting on right side of the loop on time **t=2 s**, giving its direction and sense.

2,5 points

3. Una espira cuadrada de lado **a** tiene una resistencia eléctrica **R,** y se encuentra dentro de un campo magnético uniforme, variable en el tiempo según la expresión $\mathbf{B=B_0 t}$ T y perpendicular a la espira ($\mathbf{B_0}$ es una constante positiva y **t** es el tiempo). Calcula:

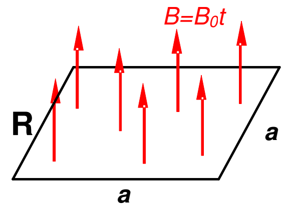
a) (1) Flujo del campo magnético a través de la espira en función de **t**.

b) (0,5) La fuerza electromotriz inducida en la espira.

c) (0,5) La corriente que circula por la barra, indicando clara y razonadamente su sentido (horario o antihorario).

d) (0,5) La fuerza que actúa sobre el lado derecho de la espira en el instante **t=2 s**, indicando su dirección y sentido.

2,5 puntos



a) Magnetic field is uniform and parallel to surface vector at any point of surface of loop. Then, at any time t

$\phi(\mathrm{t}) = \mathrm{BS} = \mathrm{B_0 t a^2}$ Wb

b) $|\varepsilon| = \frac{d\phi}{dt} = \mathrm{B_0 a^2}$ V

c) $\mathrm{i} = \frac{\varepsilon}{\mathrm{R}} = \frac{\mathrm{B_0 a^2}}{\mathrm{R}}$ A   As magnetic flux goes to up and this magnetic flux is increasing on time ($\phi = \mathrm{B_0 t a^2}$), induced current should produce a magnetic field opposite to this increasing flux. A current flowing along the loop in clockwise sense produces a magnetic field and a magnetic flux to down. Then, the answer is **clockwise sense.** As magnetic field is uniform along the right side of loop, the force acting on this side when indiced current is flowing along it, comes from equation $\vec{F} = i\vec{L}\times\vec{B}$. Induced current is not depending on time, but magnetic field depends on time. When t=2 s, B=2B_0 and taking in account that $\vec{L}$ and $\vec{B}$ are penpendicular:

$\mathrm{F} = \mathrm{iLB} = \frac{\mathrm{B_0 a^2}}{\mathrm{R}} \mathrm{a} 2\mathrm{B_0} = \frac{2\mathrm{B_0^2 a^3}}{\mathrm{R}}$ N This force acts in the same plane of loop to left.

4. A circuit is made up by a **R=3 Ω** resistor in series with a **L=5 mH** coil and a **C=1 mF** capacitor. Instantaneous intensity flowing along circuit is $\mathbf{i(t) = 5\cos(1000t - 30^\circ)}$ **A.** Compute:

a) Instantaneous voltage on terminals of resistor.

b) Reactance of coil and capacitor (X_L and X_C).

c) Instantaneous voltage on terminals of coil.

d) Impedance, phase lag and instantaneous voltage on terminals of circuit.

e) Compute the resonant frequency of circuit.

Note: You can both use degrees or radians to solve this exercise.

2,5 points (0,5 points each paragraph)

4. Un circuito está formado por una resistencia **R=3 Ω** en serie con una autoinducción **L=5 mH** y un condensador **C=1 mF.** La intensidad instantánea que circula por el circuito es $\mathbf{i(t) = 5\cos(1000t - 30^\circ)}$ **A.** Calcular:

a) La tensión instantánea en bornes de la resistencia.

b) Reactancias de autoinducción y condensador (X_L y X_C).

c) Tensión instantánea en bornes de la autoinducción.

d) Impedancia, ángulo de desfase del circuito y la tensión instantánea total en bornes del circuito.

e) Calcula la frecuencia de resonancia del circuito.

Nota: Podéis utilizar tanto grados sexagesimales como radianes para resolver este ejercicio.

2,5 puntos (0,5 puntos cada apartado)

a) Phase lag on a resistor is zero, and amplitude of voltage is the product of resistance and amplitude of intensity. So, $u_R(t) = 3\cdot 5\cos(1000t - 30^\circ) = 15\cos(1000t - 30^\circ)$ V

b) $X_L = L\omega = 5\cdot 10^{-3}\cdot 1000 = 5\ \Omega$ $X_C = \frac{1}{C\omega} = \frac{1}{1\cdot 10^{-3}\cdot 1000} = 1\ \Omega$

c) On a coil, phase lag is 90º and amplitude of voltage is the inductive reactance multiplied by the amplitude of intensity: So, $u_L(t) = 5\cdot 5\cos(1000t - 30^\circ + 90^\circ) = 25\cos(1000t + 60^\circ)$ V

d) $Z=\sqrt{R^2+(L\omega-1/c\omega)^2}=\sqrt{3^2+(5-1)^2}=5\ \Omega$ $\qquad tg\varphi=\frac{L\omega-1/C\omega}{R}=\frac{5-1}{3}=\frac{4}{3}\Rightarrow\varphi=53^{o}$

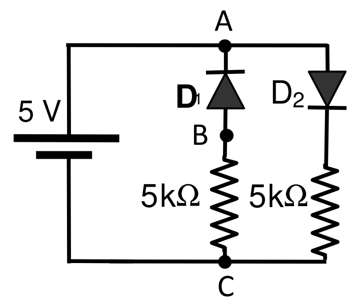
$u(t)=5\cdot 5\cos(1000t-30^{o}+53^{o})=25\cos(1000t+23^{o})\ V$

e) Resonant frequency (f_0) is that verifying that X_L=X_C:

$$L\omega_0=\frac{1}{C\omega_0}\Rightarrow\omega_0=\sqrt{\frac{1}{LC}}=\sqrt{\frac{1}{5\cdot 10^{-3}\cdot 1\cdot 10^{-3}}}=\sqrt{0{,}2\cdot 10^6}=447{,}2\ \text{rad/s}\Rightarrow f_0=\frac{\omega_0}{2\pi}=71{,}2\ \text{Hz}$$

5. On circuit on picture, drop forward voltage of both diodes is $\mathbf{V_u = 0{,}7\ V}$. Internal resistance can be neglected.
a) (1) State if each diode is forward or reverse biased.
b) (0,5) Compute the intensities I_1 and I_2 flowing along each diode.
c) (0,5) Compute difference of potential between points A and B.
2 points

5. En el circuito de la figura, la tensión umbral de ambos diodos es $\mathbf{V_u = 0{,}7\ V}$. La resistencia interna es despreciable.
a) (1) Indica la polarización de cada uno de los diodos (directa o inversa).
b) (0,5) Calcula las intensidades de corriente I_1 e I_2 que circulan por ellos.
c) (0,5) Calcula la diferencia de potencial entre los puntos A y B.
2 puntos



a) According the polarity of power supply, D_1 is reverse biased and D_2 is forward biased.
b) I_1=0 (is reverse biased) $\quad I_2$=(5-0,7)/5=0,86 mA
c) As there isn't intensity flowing along branch of D_1, points B and C have the same potential and $V_A-V_B=V_A-V_C=5\ V$

FORM

Magnetic Forces $\quad \vec{F}=q(\vec{v}\times\vec{B})\quad d\vec{F}=I\,d\vec{l}\times\vec{B}\quad \vec{\mu}=N\cdot I\cdot\vec{S}\quad \vec{\tau}=\vec{\mu}\times\vec{B}\quad V_H=\frac{I\cdot B\cdot d}{n\cdot e\cdot S}$

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

$B=\frac{\mu_0 I}{2R}\quad \oint_L\vec{B}\cdot\vec{dl}=\mu_0\sum I\quad B=\frac{\mu_0 NI}{l}$

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

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

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

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

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