Final Exam 2049H

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Complex Impedance

Capacitor: $\frac{1}{i\omega C}$, **Inductor:** $i\omega L$

Problem 1

True or False Questions

(a) Flux of Magnetic field through any closed surface is zero.

TRUE

(b) Magnetic field can be used to change the energy of charged particles.

FALSE

(c) A straight current-carrying wire has a finite inductance.

TRUE

(d) Inductors can store energy.

TRUE

(e) Electric field inside an ohmic resistor wire is directly proportional to current through it.

TRUE

Problem 2

At t = 0, a charged particle with charge of q sits at (0,0,0)=(x,y,z). At this point, an electric field pointing in x direction is turned on. The magnitude of electric field is E. [$\vec{E} = (E,0,0)$]

(a) Write force on the particle in the vector form
(b) Find acceleration in vector form
(c) Find the location of the particle at $t=t_f$

a) $\vec{F} = (qE, 0, 0)$

b) $a = \left(\frac{qE}{m}, 0, 0\right)$

c) $\left(\frac{qE}{2m}t^2, 0, 0\right)$

Problem 3

A charged particle with charge of q has been accelerated through a potential drop of 1000 V. After this initial potential drop, the particle does not experience any force due to electric field. You may assume that the particle is moving from left to right.

(a) Calculate the energy of the particle. 1 eV = 1.6×10^{-19} J.
(b) Calculate its velocity if the mass of the particle is given by m.

After a while, the charged particle enters a space with magnetic field, which is pointed perpendicular to the direction of its motion. The magnitude of magnetic field is 1 Tesla and is pointed out of the paper.

(c) Calculate the force on the particle due to magnetic field.
(d) Calculate the magnitude of velocity of the particle in this magnetic field.
(e) Draw the motion of the particle in magnetic field.
(f) Does the magnetic field change the energy of the particle?

a) 1000 eV $\quad 1.6\times10^{-16}$ J

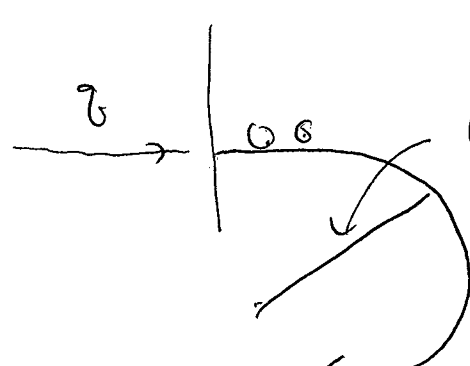
b) $\frac{1}{2}mv^2 = 1.6\times10^{-16}$ J

$v = \sqrt{\frac{3.2\times10^{-16}}{m}}$ m/s

c) $F = qvB = \left(q\sqrt{\frac{3.2\times10^{-16}}{m}} \cdot 1.0\,T\right)$ N

d) $|v| = \sqrt{\frac{3.2\times10^{-16}}{m}}$ m/s

e)

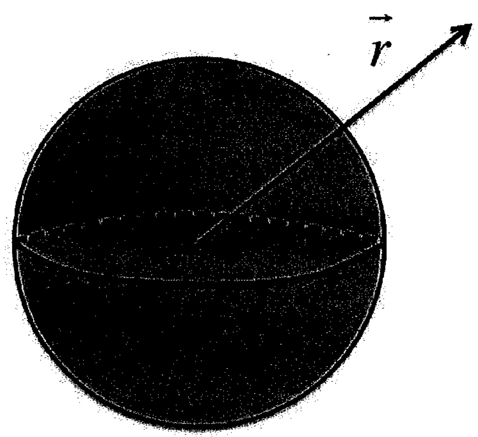


CIRCULAR MOTION

f) <u>NO</u>

Problem 4

Uniformly Charged Solid Sphere (note it is not *metallic*) has radius R and volume charge density ρ.



Calculate electric field (its dependence on r)

(a) for outside the sphere
(b) for inside the sphere

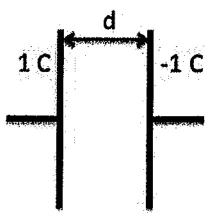
Calculate potential (its dependence on r)

(c) for outside the sphere
(d) for inside the sphere

(e) Does potential vary inside the sphere?

ANSWER SAME AS IN THE PROBLEM IN THE OTHER PRACTICE EXAM

Problem 5



A parallel plate capacitor has been charged so that one plate has a charge of 1 coulomb and the other plate has a charge of -1 coulomb. The distance between the plates is 1m and the area of each plate is 1 m^2.

(a) Calculate the electric field inside the capacitor assuming that there is no fringe field.
(b) Calculate the potential difference between the plates
(c) Calculate the capacitance of the parallel plate capacitor
(d) What is the energy stored in the capacitor?
(e) What happens to the voltage difference if the distance between the plates is reduced to 0.1 m.
(f) If the space between the plates are filled (completely) by a material with dielectric constant of 4.

a) $E = \frac{\sigma}{\varepsilon_0} = \frac{1\,C/m^2}{8.85 \times 10^{-12}}$

b) $V = \frac{\sigma}{\varepsilon_0} d$

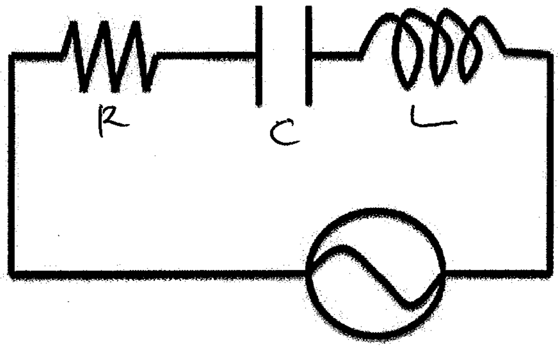
c) $C = \frac{\varepsilon_0 A}{d}$

d) $U = \frac{1}{2} C V^2$

e) VOLTAGE DIFFERENCE WILL REDUCE BY A FACTOR OF 10

f) IT GETS QUARTERED

Problem 6



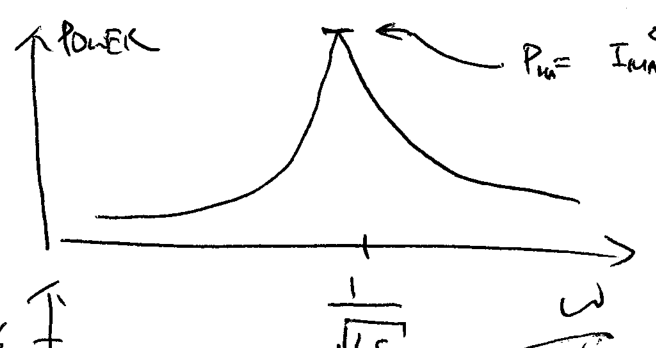
Given a series RLC circuit as drawn and an oscillating driving voltage answer following questions. $V(t) = V_{\max}\cos(\omega t)$

(a) Calculate the total impedance of the circuit
(b) What is the expression for the phase of the current through the circuit with respect to the driving voltage? You can assume $I(t) = I_{\max}\cos(\omega t - \phi)$.
(c) Draw a graph for power delivered versus driving frequency for the circuit. Be sure to define x axis as frequency, y axis as power delivered and clearly indicate the maximum power delivered.
(d) Draw a graph for the phase of the current with respect to the voltage.
(e) Calculate the frequency at which power delivered to the circuit is maximized.

a) $Z = R + i\omega L + \frac{1}{i\omega C}$

b) $\phi = \arctan\left(\frac{\omega L - \frac{1}{\omega C}}{R}\right)$

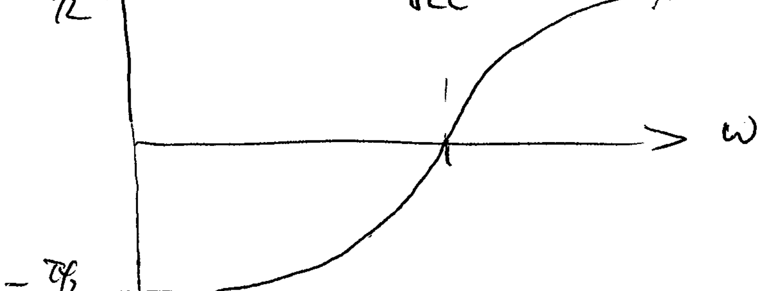
c)



$P_{M} = I_{MAX}^2 R = \left(\frac{V}{R}\right)^2 R$

$= \frac{V_{MAX}^2}{R}$

d)



e) $\frac{1}{\sqrt{LC}}$

Problem 7

A solenoid has a length l, N total coils and cross sectional area of A (πR^2)

(a) Calculate the inductance of this solenoid
(b) If a current, I, flows through the solenoid, how much energy is stored in the solenoid?
(c) What is the voltage drop across the inductor when there is no change in current?
(d) What happens to the voltage drop across the inductor when the current is changed at a pace of α amperes per second?

a) Solenoid $B = \mu_0 n I = \mu_0 \frac{N}{l} I$

$\Phi_B = \mu_0 \frac{N}{l} I A = \frac{L}{N} I$

~~$L = N \frac{d\Phi_B}{dI}$~~ $L = \mu_0 \frac{N^2}{l} A$

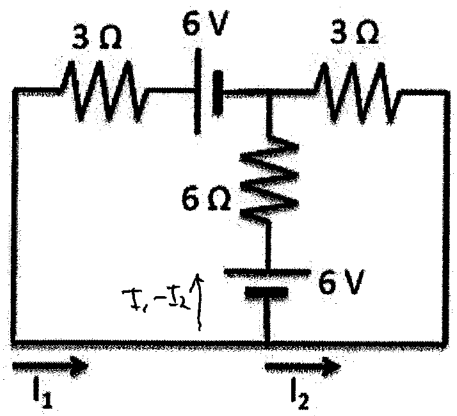
b) $\frac{1}{2} L I^2$

c) 0

d) $|\Delta V| = |L \frac{dI}{dt}| = L\alpha$

Problem 8

Calculate I_1 and I_2 in the circuit shown left.



$$6 - 6(I_1 - I_2) + 6 - 3I_1 = 0 \quad (1)$$

$$-9I_1 + 6I_2 = -12$$

$$9I_1 - 6I_2 = 12 \quad (1)$$

$$-3I_2 + 6(I_1 - I_2) - 6 = 0$$

$$6I_1 - 9I_2 = 6 \quad (2)$$

$$9I_1 - 6I_2 = 12$$

$$9I_1 - \frac{27}{2}I_2 = 9$$

$$\frac{15}{2}I_2 = 3$$

$$9I_1 - \frac{12}{5} = \frac{60}{5}$$

$$9I_1 = \frac{72}{5}$$

$$\boxed{I_2 = \frac{2}{5}\,A}$$

$$\boxed{I_1 = \frac{8}{5}\,A}$$