Electromagnetism, Optics and Waves

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Observations made Sept 18, 2010 UC Davis GRE Prep

Observations

The largest general misunderstanding was with circuitry, and circuit elements. This is something you can only know by memorization

The second most common mistakes I found were with calculating EMF induced by a change in flux. Remember flux change can be either dB or dA

General solution guidance

Eliminate unreasonable solutions by physical arguments:

Limits:

R -> inf. R -> 0 M -> inf. M -> 0 t -> inf t -> 0

Eliminate unreasonable solutions by Unit Analysis:

always try to work in one unit system, MKS, CGS, or other, but don’t have m and cm in one problem.

Look for common forms, such as potentials ~1/x

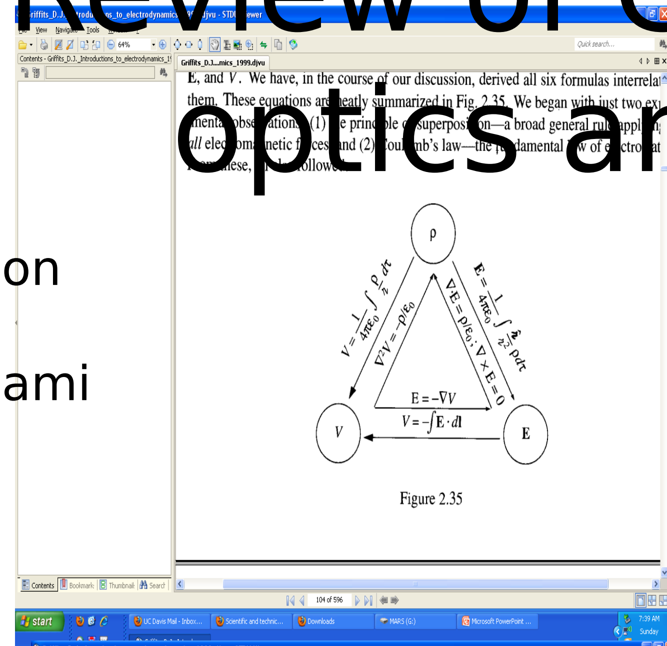
No where is using physical arguments and unit analysis more important than with E/M

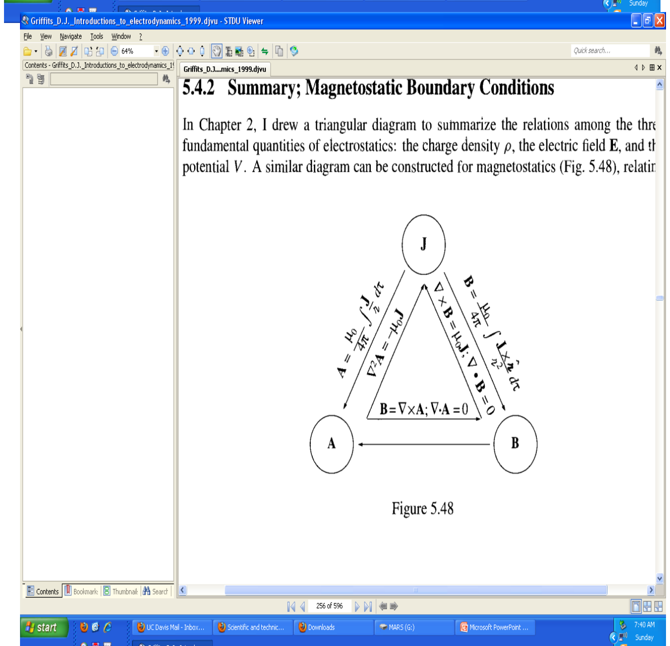
There are many E/M problems which cannot be solved by trivial methods (hence why Jackson exists) E/M has the advantage that it deals with easily comprehendible objects (charge, simple non-relativistic space-time...) all with physical units! Take advantage.

PS, many problems (unless it has a memorized equation) are solved by

Review of General E/M, optics and Waves

Griffiths "Introduction to Electrodynamics"
Pg 87, and 240





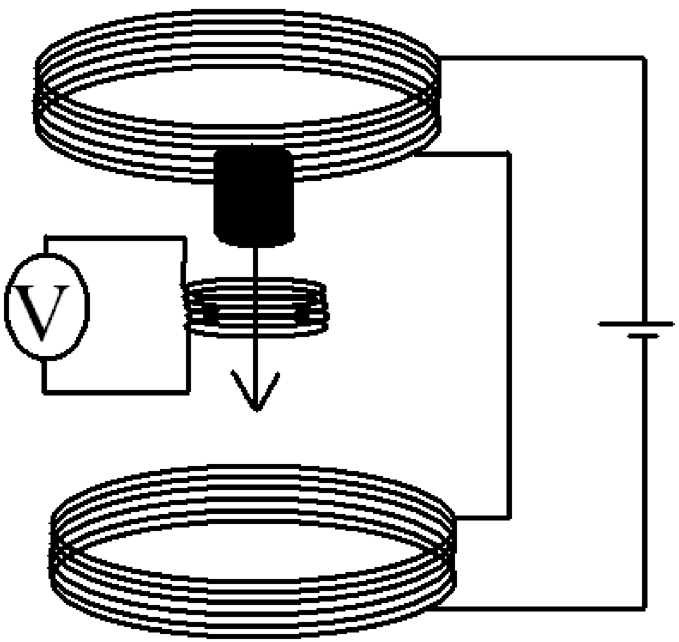
Lorentz Force Law F = QV x B
Force on a current F = IL x B
Capacitance C = Q/V
Energy in a capacitor E = 0.5CV2
RLC resonance ω = (LC)-0.5
Ohm's Law V = IR
AC Impedance Z = (1/ωC)
Power from a resistor P = I2 R
Faraday's Law EMF = -dΦ/dt

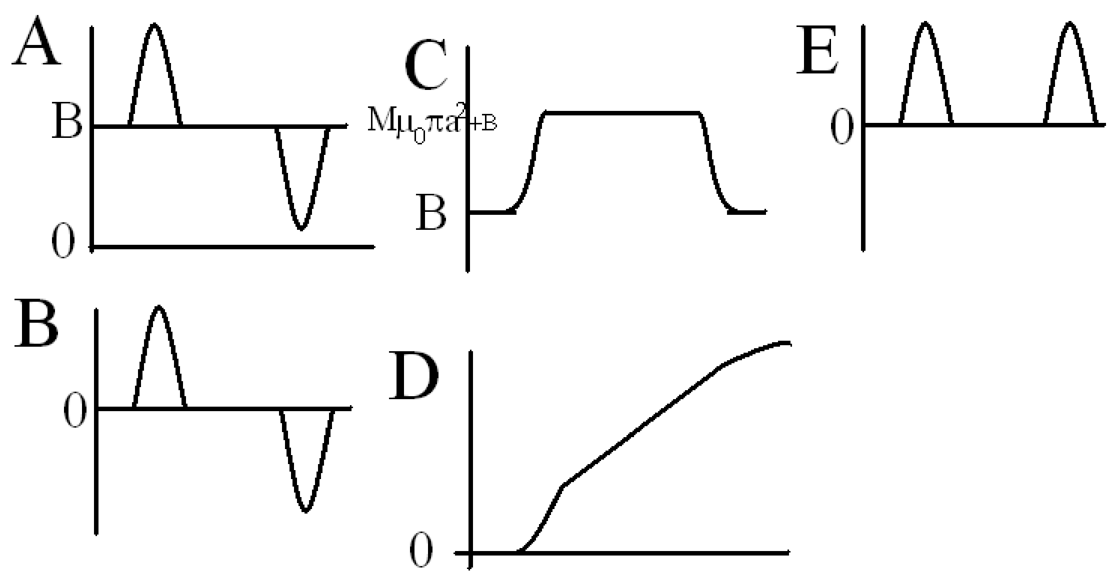
Constructive diffraction m λ = 2 d Sin(θ)
Bending at interface n1 Sin(θ1) = n2 Sin(θ2)
Magnification M = fo / fe

REMEMBER 2πf = ω
Right hand Rule
180o phase flip if reflecting off surface with n2>n1

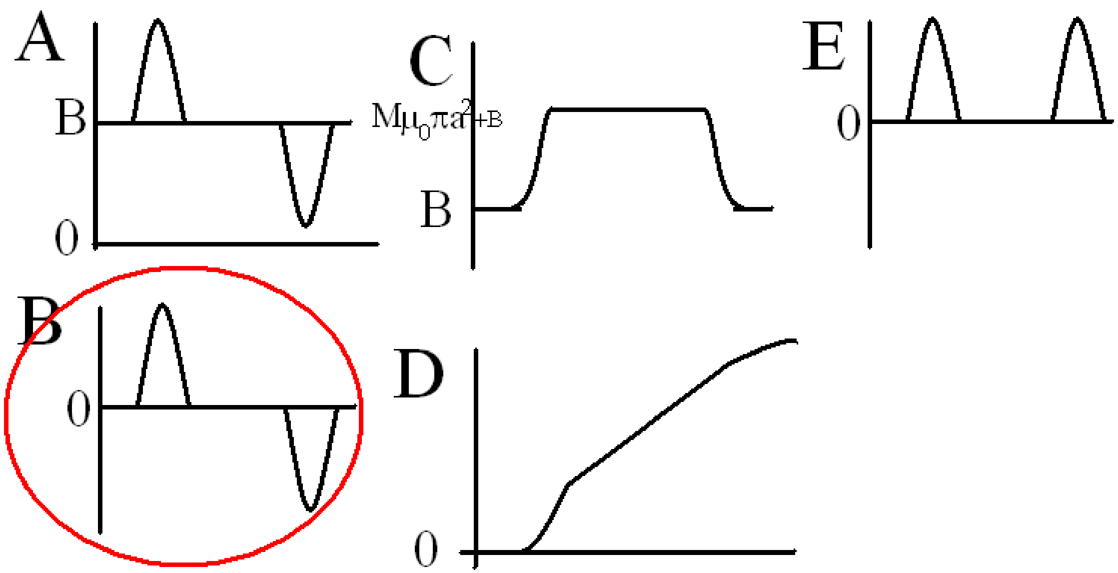
Example problem 1

In condensed matter, we use an instrument called a Vibrating Sample Magnetometer (VSM). A VSM applies a constant magnetic field, B, through a loop of wire, then drives a magnetic sample back and forth through this loop. The EMF is measured, and the magnetization is calculated. If our sample is a simple cylinder, with magnetization M, and radius A, please select the plot which describes the EMF.





Solution



The correct answer is B.

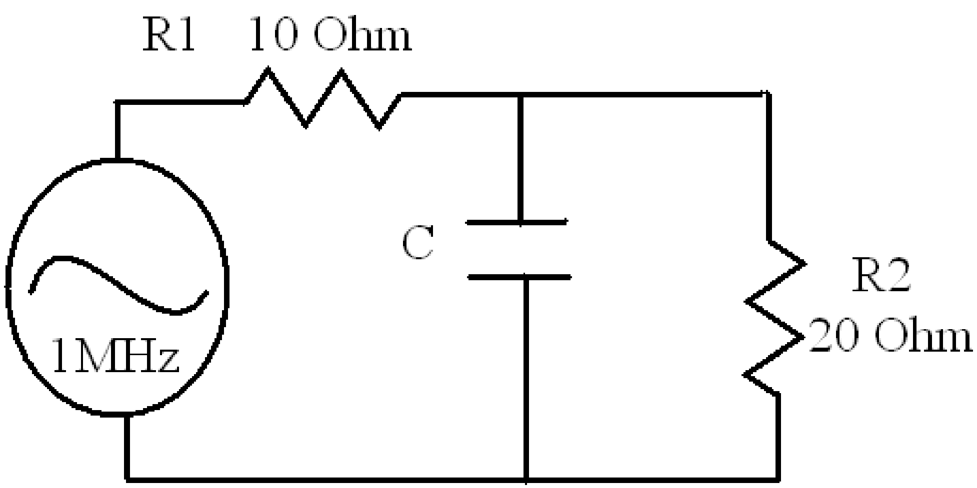
Solution A is similar to B, but offset by some constant (presumably because of the constant magnetic field). Remember though, the derivative gets rid of all constants

Solution C is similar to the magnetic flux through the loop. The EMF is just the derivative

Solution D is the integral (rather than the derivative) Integral [phi dt].

Example problem 2

Given the below circuit, what is the value of the capacitance if half the current is going through the resistor R2? (the value of C closest to…)



a. 50 nF
b. 5 nF
c. 0.5 nF
d. 50 pF
e. 5 pF

Solution

There is a simple voltage divider between the capacitor and R2. If they have the same impedence, the current should split evenly.

Z = $(1/\omega C)$ = 20 Ohm
C = $(1/(\omega 20))$

$2\pi f = \omega = 1E6 * 2\pi$

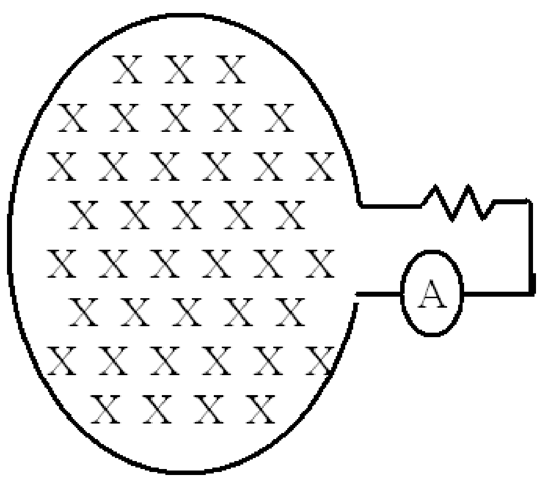
C = 1/(20*(~6)*1E6) ~1/12 * 1E-6 ~ 0.1 * 1E-6 = 10nF

Closest is 5nF (B)

[true answer is 7.96 nF]

Example Problem 3

If the loop below has a diameter of 10cm, and the magnetic field through it is decreasing at a rate of 100 Kelogauss/sec, and R has a value of 3000 mOhm, what is the Current regist mmeter?



a. 1 mA
b. 1 A
c. 100 mA
d. 25mA
e. 250 mA

Review of important points

The correct answer is D

convert to MKS units:

100kG = 10T   10cm diam = 5cm radius = 0.05m
3000mOhm = 3Ohm

EMF = A * dB/dt = $\pi P2 * \delta B/\delta\tau = (3.14)*0.052 * 10 \sim 3*2.5E{-}3*10$

$EM\Phi \sim 7.5E{-}2 = 0.075\varsigma$

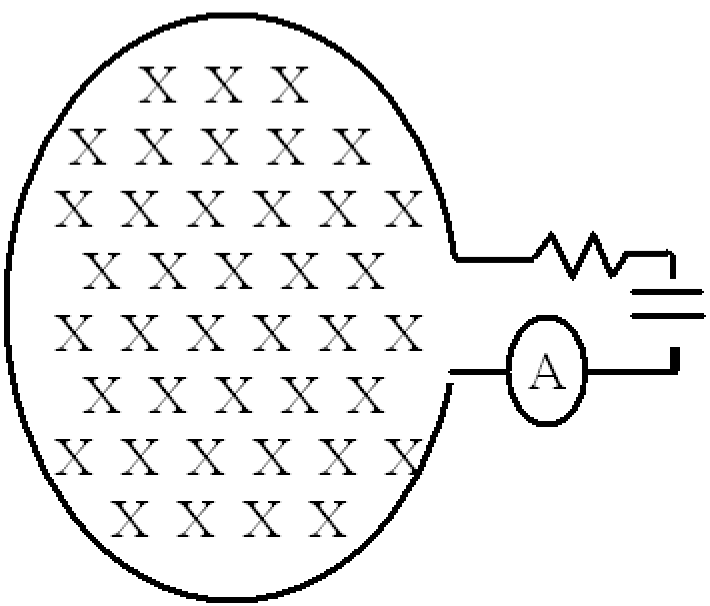
$I = \varsigma/P = 0.075/3 = 0.025A = 25\mu A\ (\Delta)$

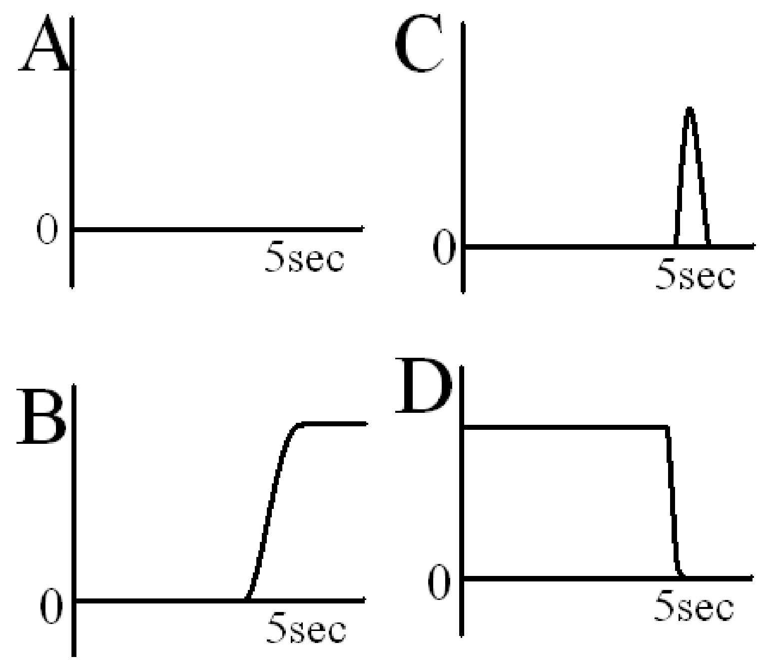
3B

If we then put a capacitor in the circuit, then attempted the same experiment, but after 10 min, 5 sec our power supply failed, and the field nearly instantly became 0, which graph

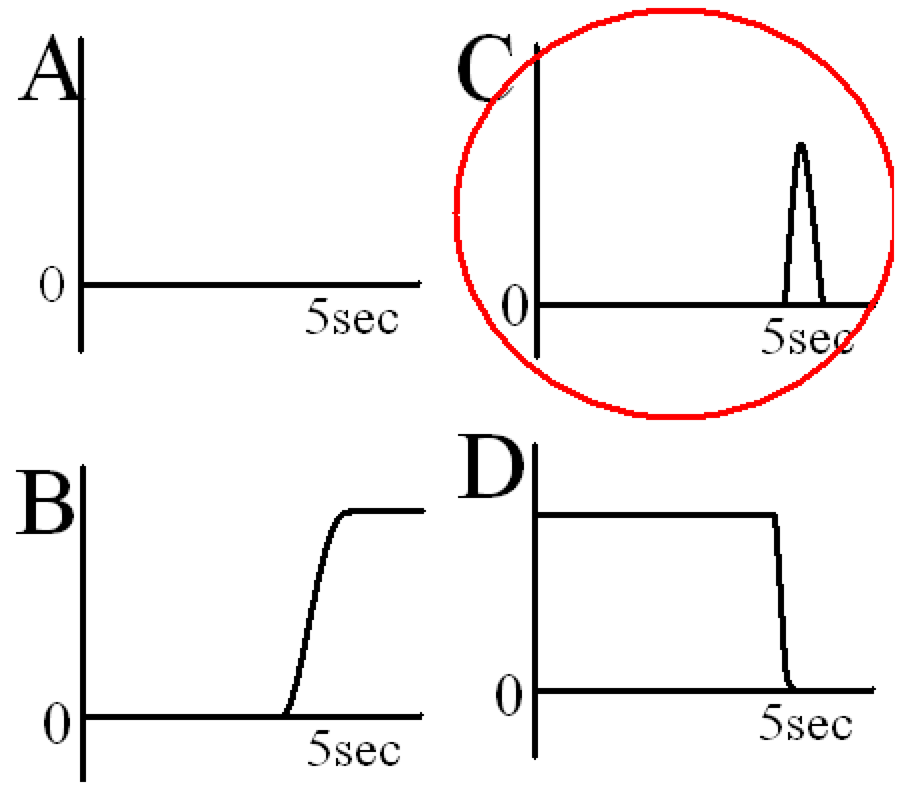
gister

.0:0





The correct answer is C, the capacitor acts as a high pass filter. The EMF initially is DC, so it will not pass the capacitor, so D is incorrect. When there exists a large dI/dt (essentially a pulse) the capacitor allows current flow, but afterwards, no EMF exists at all, so B is incorrect, and so is A. C is the correct answer.



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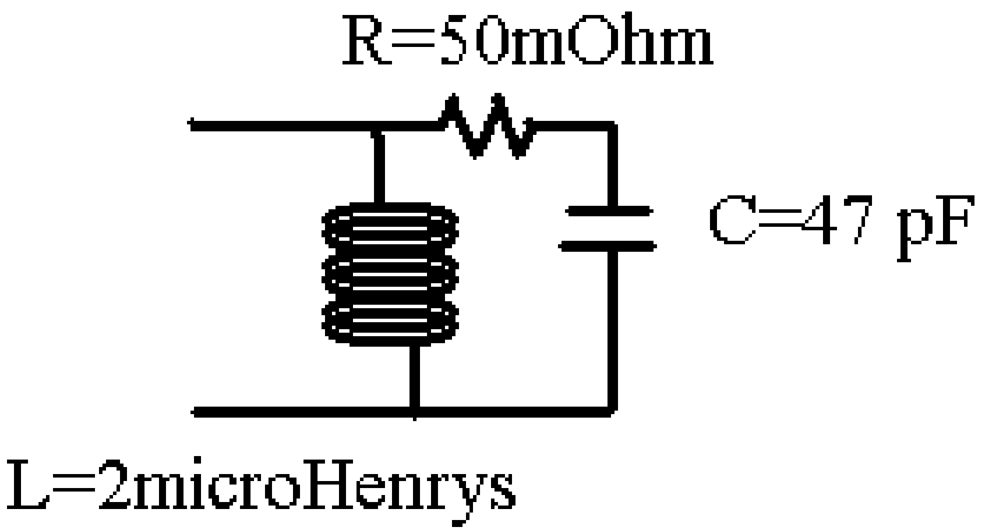
At what frequency does the below circuit oscilate?



a. 10 GHz
b. 100 kHz
c. 100MHz
d. 1.6MHz
e. 16MHz

Correct answer is E

ω = 1/σθρτ (ΛΧ)

Λ=2Ε–6   Χ = 47Ε–12

ΛΧ ~100Ε–18

Σθρτ(ΛΧ) = 10Ε–9

ω = 1Ε8

φ=ω/2π = 1Ε8/6.28 = 16Ε6 = 16ΜΗζ

General Guidance

Get plenty of sleep the night before and eat breakfast before hand

Don’t stress, it is a negative feedback, so it will only get worse

I usually take most of the day before off, it will get you clear of mind

Take the test the way you study: if you didn’t study tweeked out on caffeine, then don’t go to the test all tweeked out on Red Bull + Coffee