**Practice Problem Set on AC circuits and EM waves - Solutions**

**Questions 1 and 5 are 1 point questions, Questions 2, 3, 4, 6, 7, and 8 are 3 point questions**

1. **How is an LRC circuit similar to a mechanical harmonic oscillator? Which component of the circuit acts like a “mass”? Which component of the circuit acts like “friction”?**

An LRC circuit is similar to a mechanical oscillator because they alternate between potential and kinetic energy. The component of the circuit that acts like a mass is the inductor and the component that acts like friction is the resistor.

1. **Use Gauss’ Law and Ampere’s Law to find both the capacitance per unit length and the inductance per unit length of a coaxial cable with an outer radius of 4.5 mm and an inner radius of 1.5 mm. Assume the space between the two conductors is filled with air.**
* Solving for capacitance per unit length:
* Solving for Inductance per unit length:
1. **An AC generator with a variable frequency is connected across a 45 cm piece of the coaxial cable described in Question 2. If the cable has minimal resistance, at what frequency will the cable resonate? If the resistance of the cable is 2Ω per meter, what is the new resonant frequency?**
2. =
3. The new resonant frequency is the same as the , 1.4 10-7 Hz, because for small resistances the resonance frequency is not a function of resistance and therefore has no effect on the frequency.
4. **Two circular loops of wire with radius 8.5 cm are sitting one on top of another such that the total flux through the first loop travels through the second loop, and vice versa. What is their mutual inductance?**

In this case the mutual inductance of the two loops is the same as the self-inductance of a single circular loop of wire. For a loop of radius ‘r’ and wire radius ‘a’ this inductance is given by:

H

5)

What are Maxwell’s Equations? Which term of which equation was included by Maxwell in order to complete the description of electric and magnetic fields?

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| Integral form in the absence of magnetic or polarizable media:I. [Gauss' law for electricity](http://hyperphysics.phy-astr.gsu.edu/hbase/electric/maxeq2.html#c1)II. [Gauss' law for magnetism](http://hyperphysics.phy-astr.gsu.edu/hbase/electric/maxeq2.html#c2)III. [Faraday's law of induction](http://hyperphysics.phy-astr.gsu.edu/hbase/electric/maxeq2.html#c3)IV. [Ampere's law](http://hyperphysics.phy-astr.gsu.edu/hbase/electric/maxeq2.html#c4) |

Question 6

A capacitor has a capacitance of 250 nF and a voltage is placed across it which grows as a function of time as: V(t) = 240 mV/s3 × t3. What is the displacement current as a function of time?

C = 250 nf

 v(t) = 240 mV/s^3 \* t^3

I (displacement current) = ℇ d 𝐼(Electric flux) / dt

 = ℇ d/dt ∯ |E| \* |dA|

 = ℇ d/dt |E| ∯ dA

 = ℇ d/dt |E| A

 = ℇ A d/dt E

 = ℇ A d/dt V/d

 = ℇA/d d/dt V

 = C d/dt V

 = (2.5 X 10 ^ -7 F) \* (3t^2) \* (240 X 10 ^ -3 v/s^3)

 = 1.8 X 10 ^ -7 A/S ^ 2 (t ^ 2)

Question 7

An electromagnetic plane wave at a certain location has an electric field pointed up which is given as a function of time as E = 54 V/m × sin (6x106 Hz × t). The magnetic field at the same location points south when the electric field points up. What is the Poynting vector at this location for this wave as a function of time? What is the wavelength of the wave?

E = 54 V/m X sin(6 X 10 ^ 6 Hz X t ) up

 S = E X B / μ (S point east)

 S = |E| \* |E| / c \* μ

 = [((54 v/m) ^ 2) \* (sin^2 (6 X 10 ^ 6 Hz x t))] / [(4pi X 10 ^ -7 Tm/A) (3 X 10 ^ 8 m/s)]

 = 7.7 sin ^ 2 (6 X 10 ^ 6 Hz X t) w/m ^ 2 east

v = 𝝺λ 𝑓 = c

λ = c / 𝑓 = 2 pi c / w = [2 pi X (3 x 10 ^ 8 m/s)] / [6 X 10 ^ 6 Hz] = 314 m

Question 8

The wave in question 3 is incident on a square piece of foil which is 3.6 m long on each side. If the wave is completely absorbed by the foil for 35 seconds, how much energy does the foil absorb? How much momentum is absorbed by the foil for the same time interval? Assume the foil is set up in the south-up plane.

S(average) = I = P (average) / Area = (Energy / Δt) / Area

 Energy = S (average) X Area X Δt

 = [|E (max) ^ 2| \* A \* t] / 2 \*μ\* c

 = [(154 V/m) ^ 2 \* (3.6 m) ^ 2 \* (35 s) ] / [2 \* (4pi X 10 ^ -7 Tm/A) \* (3 X 10 ^ 8 m/s)]

 = 1750 J

| P | (Momentum) = E / C = 1750 J / (3 X 10 ^ 8 m/s) = 5.8 X 10 ^ -6 kg \* m/s in East