Physics 202-Section 2G
Worksheet 8

Formulas and Concepts

- Capacitors : electric fields :: Inductors : magnetic fields. Like capacitors create electric fields by storing charge, inductors create magnetic fields by running a current through a solenoid.
    - Magnetic flux is related to inductors according to: $\boldsymbol{\Phi = LI}$, where L is a quantity known as inductance.
    - Electromotive force is related to inductance according to : $\mathcal{E} = -\boldsymbol{L\frac{\Delta I}{\Delta t}}$
    - The units for inductance are Henry (H). 1 H = 1 T*m^2/ ampere
- Other important formulas for inductors:
    - Energy stored in an inductor: $\boldsymbol{W = \frac{1}{2}LI^2}$
    - Inductance of a solenoid: $\boldsymbol{L = \frac{\mu_0 N^2 A}{l}}$, where N is number of turns of the wire, A is area of one loop of the solenoid, and l is the length of the solenoid.
- Capacitors and inductors are what's known as "reactive elements" in circuit. The voltage across them and current through them vary with respect to time.
- Alternating current:
    - In a circuit with direct current, the voltage supplied by a battery is constant. However, in a circuit with alternating current, the voltage oscillates like a sine wave. Voltage varies with time according to the formula: $\boldsymbol{V = V_0 \sin(\omega t)}$ where **ω = 2πf** (f is frequency of the current).
    - Current is dependent on voltage, so it also varies with time according to the formula: $\boldsymbol{I = I_0 \cos(\omega t)}$**.**
    - If we wanted to find average voltage or average current, we would divide the maximum voltage or current by √2.
    - Average current and average voltage are related in a similar way as voltage and current are related in DC circuits. In an AC circuit: $\boldsymbol{V_{rms} = I_{rms}X}$, where X is capacitive reactance or inductive reactance (measured, like resistance, in ohms).
    - $\boldsymbol{X_L = \omega L}$ and $\boldsymbol{X_C = \frac{1}{\omega C}}$

1. A solenoid with an inductance of 0.0056 H is 4.5 cm long and consists of 545 loops. What is the radius of each loop of the solenoid?

0.0147 m. Use the formula $\boldsymbol{L = \frac{\mu_0 N^2 A}{l}}$**.** Plug in 545 for N and 0.045 m for l, and 0.0056 for L. Solve for area. This are is equal to π*r^2, so divide by π and take the square root to find the radius.

2. The amount of current through an inductor is 2.23 A when magnetic flux is equal to 10 Wb. When the current drops to 0 A in the inductor over a period of 14 ms, what electromotive force is generated?

714.29 V. This question gives more information than is necessary. EMF = Δflux/Δtime, so divide 10 by 0.014s. You can also do Flux = LI, solve for L, the plug that into EMF = L(Δcurrent/Δtime), but it will give you the same answer and that's more steps.

3. A current of 20 A exists in a solenoid. That current drops to zero in a period of 88 milliseconds. In this process, an electromotive force of 8400 volts is induced in the solenoid.

a. What is the inductance of the solenoid?

36.96 H. $\mathcal{E} = -\boldsymbol{L}\frac{\boldsymbol{\Delta I}}{\boldsymbol{\Delta t}}$, EMF is 8400, change in current is -20A, and time is 0.088s. Plug in and solve for L.

b. What is the power dissipated (really the rate energy should be removed) from the solenoid during this process?

84000 watts. This question really should have come after part C. Take the answer to part C (which is work) and divide by the time (0.088) to get power because power = work/time.

c. How much energy is initially stored in the solenoid?

739.2 J. Energy stored in an inductor is: $\boldsymbol{W} = \frac{\mathbf{1}}{\mathbf{2}}\boldsymbol{L}\boldsymbol{I}^{\mathbf{2}}$. We know L from part A, and I is given (20A). Plug in and solve for W.

4. A current with frequency 13400 Hz runs through a 25 mH inductor.

a. What is the inductive reactance of this inductor?

2104.87 Ω. Inductive reactance is $X_L = \omega L$. $\omega = 2\pi f$. First find ω by substituting in what you're given for frequency, then multiply that by the inductance (0.025 H).

b. If a capacitor has the same reactance at this frequency, what would its capacitance be?

5.64e-9 F. If the capacitive reactance is the same as the reactance in part A (2104.87), then we know that $X_c = 1/(\omega C)$. The frequency is the same here, so our ω won't change, so the capacitance will be $1/(X_c\omega)$.