Name: _____

Answer the questions in the spaces provided on the question sheets. If you run out of room for an answer, continue on the back of the page.

Multiple choice

1. (2 points) The electric force and the magnetic force are the following type of force:

   ○ a contact force
   √ **a field force**
   ○ a normal force

2. (2 points) Ampere's law relates the the integral of the magnetic field around a loop with

   ○ Charge enclosed
   ○ Motion of Charges in loop
   √ **Current Enclosed**
   ○ Magnetic Charges

3. (2 points) The difference between an AC circuit and a DC circuit is:

   ○ AC circuits are not full loops, DC circuits have full loops.
   ○ DC circuits are always in series while AC circuits are in parallel.
   √ **AC circuits have non-constant oscillating voltage, DC currents have constant voltage.**
   ○ AC circuits have constant voltage, DC currents have oscillating voltage.

4. (2 points) A conductor is an object that:

   √ **that has free electrons and can transmit charges**
   ○ that doesn't have free electrons and can't transmit charges
   ○ that can transmit charges between objects of only one charge
   ○ do not experience electric forces

5. (2 points) The Millikan Oil-Drop Experiment proved that:

   ○ Showed that charges are continuous.
   ○ Showed that electrons are massless.
   ○ Showed that the electric field only interacts with electrons.
   √ **Showed that charges come in integer multiples of the elementary charge e.**

6. (2 points) Gauss's law tells us that the charges are

- ⃝ never come in pairs.
- √ **Equal to the flux passing through an imaginary 3d surface enclosing the charges**
- ⃝ inversely related to the flux passing through a loop around the charges.

7. (2 points) The electric potential energy is a [   ] and the electric force is a [   ].

√ **scalar/vector**   ⃝ vector/scalar   ⃝ scalar/scalar   ⃝ vector/vector

8. (2 points) The loop rule for circuits says that

- ⃝ The current passing through a circuit junction is conserved.
- ⃝ The current passing through a loop is equal to the size of the loop.
- ⃝ The voltage across each part of the loop is the same.
- √ **The voltage drop across each part of a circuit adds up to zero.**
- ⃝ None of the above.

9. (2 points) The junction rule for circuits says that

- ⃝ The input of a circuit junction is equal to the voltage across the junction.
- √ **The input of a circuit junction is equal to the output of a circuit junction.**
- ⃝ The input of a circuit junction is equal to the equivalent resistance of the circuit.

10. (2 points) An inductor can store energy from a circuit

- ⃝ in the form of heat.
- √ **in the form of a magnetic field.**
- ⃝ in the form of resistance.
- ⃝ in the form of capacitance.

Problems

11. A spherical drop of water carrying a charge of 30 pC has a potential of 500 V at its surface (with V=0 at infinity).

(a) (3 points) What is the radius of the drop?

> **Solution:** If the surface voltage is 500 V, then,
>
> $$V = \frac{q}{4\pi\epsilon_0 r} \quad 500 = \frac{30 \times 10^{-12} C}{4\pi\epsilon_0 r}$$
>
> We solve for r to find that $r = 5.39 \times 10^{-4}$ m.

(b) (3 points) Assume the charge in the drop is distributed uniformly, using Gauss's law, create a formula for the electric field inside the charge.

> **Solution:** Gauss's law says that the net flux passing through a Gaussian sphere is equal to the charge enclosed divided by ϵ_0. The hard part of this is to find the charge enclosed. This is equal to,
>
> $$q_{enc} = q_{drop}\frac{\frac{4}{3}\pi r^3}{\frac{4}{3}\pi R^3} = q_{drop}\frac{r^3}{R^3}$$
>
> This is because the charge is uniformly distributed in the water drop that has radius R, and so the percentage of charge enclosed by a smaller sphere inside the drop is proportional to the percentage of volume that the smaller sphere has relative to the entire drop.
>
> Then we have:
>
> $$\oint E \cdot dA = E(4\pi r^2) = \frac{q_{enc}}{\epsilon_0} = \frac{q_{drop}}{\epsilon_0}\frac{r^3}{R^3}$$
>
> and the formula is:
>
> $$E = \frac{q_{drop}r}{4\pi\epsilon_0 R^3}$$

(c) (1 point) Assume that two charges are located near to each other, with one being positively charged, the other being negatively charged. Sketch the magnetic field lines for these charges (general sketch).

> **Solution:** The book has examples of these field lines.

12. Find the equivalent circuit which has one resistor and one capacitor for the following circuit. What are the charges on the capacitors?
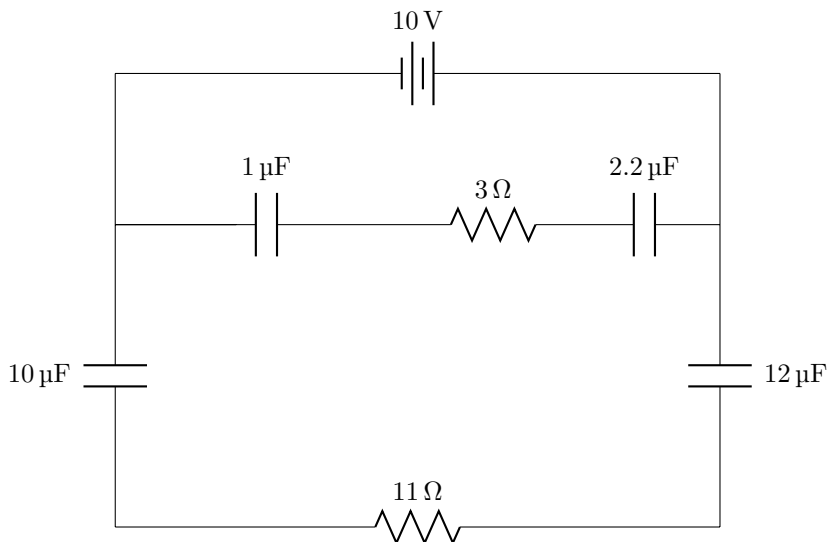
> **Solution:** The solution to this follows closely to that on the quiz (solutions are online for that). Our goal is to find the equivalent resistance and equivalent capacitance for the entire circuit. See solutions to the quiz (on the class webpage) on how to find the equivalent capacitance. For the equivalent resistance, use the equation for two resistors in parallel.

13. (4 points) A particle of mass 6.0 g moves at 4.0 km/s in an xy plane in ëgion with a uniform magnetic field given by $5.0\hat{i}$ mT. At one instant, when the particle's velocity is directed $37°$ counterclockwise from the positive direction of the x axis, the magnetic force on the particle is $0.48\hat{k}$ N. What is the particle's charge?

> **Solution:** The force on a charged particle with velocity due to a magnetic field is $F_m = qv \times B$. For this problem, we have,
>
> $$F_m = qv \times B = qvB \sin 37° = 0.48\hat{k}$$
>
> Solving for q, we find that $q = 0.03987C$.

14. (6 points) In the transformer shown below, the load resistor is 50.0 Ohms. The turn ratio $N_1 : N_2$ is 5:2 and the source voltage is 80.0 V (rms). If a voltmeter across the load measures 25.0 V (rms), what is the source resistance R_s?
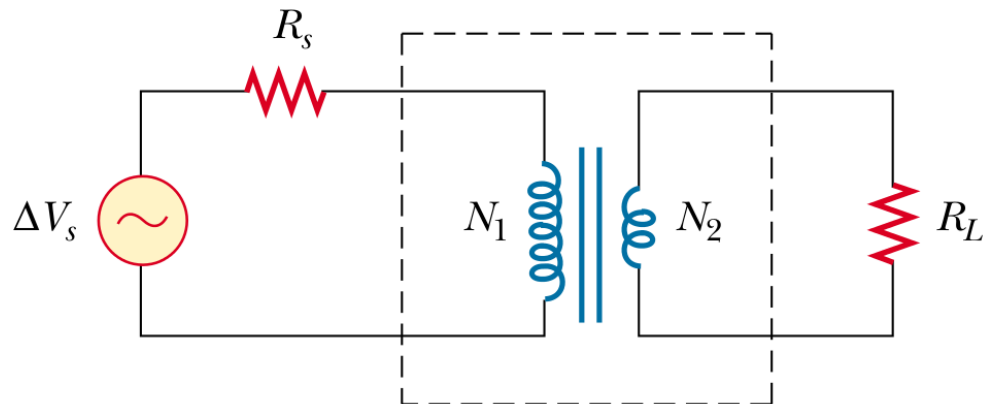
Solution:

Section 33.8 is helpful here. Take the loop rule around the left side of the transformer:

$$\Delta V_s - I_s R_s - \Delta V_1 = 0$$

and the right side,

$$\Delta V_2 - I_L R_L = 0$$

Thus the voltage drop across the load (25.0 V) is equal to V_2, and from equation 33.41,

$$\Delta V_2 = \frac{N_2}{N_1} \Delta V_1$$

or rearranged:

$$\Delta V_2 \frac{N_1}{N_2} = \Delta V_1$$

so that

$$\Delta V_1 = 2.5(25.0V) = 62.5V$$

Thus we have,

$$80 - I_s R_s - 62.5 = 0 \quad \rightarrow \quad I_s R_S = 17.5V$$

OK, so what is I_S? We need one more equation to help us out here, Equation 33.43 which shows us that the equivalent resistance of a transformer on a circuit is given as,

$$R_{eq} = \left(\frac{N_1}{N_2}\right)^2 R_L = (2.5)^2 50\Omega = 312.5\Omega$$

But since the voltage across the transformer is 62.5 V, and

$$\Delta V_1 = I_S R_{eq} \quad \rightarrow \quad 62.5V = I_S 312.5\Omega \quad \rightarrow \quad I_s = 0.2A$$

Finally, since this is the same current across the resistor R_s, and R_s has a voltage drop of 17.5 V, we find

$$\Delta V_{R_S} = I_s R_s \quad \rightarrow R_s = \frac{\Delta V_{R_S}}{I_s} = \frac{17.5}{0.2} = 87.5\Omega$$

15. (6 points) A series RLC circuit is driven by a generator at a frequency of 2000 Hz and an emf amplitude of 170 V. The inductance is 60.0 mH, the capacitance is 0.400 μF and the resistance is 200 Ohms. What is the phase constant in radians and the current amplitude?

Solution: The phase constant is
$$\tan^{-1}\left(\frac{X_L - X_C}{R}\right)$$

We must find X_L and X_C:

$$X_L = \omega L = 2\pi(2000Hz)(0.060H) = 754\Omega$$

and
$$X_C = 1/(\omega C) = 1/(2\pi 2000Hz 0.400 \times 10^{-3}F) = 199\Omega$$

Then

$$\phi = \tan^{-1}\left(\frac{754 - 199}{200}\right) = 1.22 rads$$

The current amplitude is found from

$$I = \frac{\varepsilon}{Z} = \frac{\varepsilon}{\sqrt{R^2 + (X_L - X_c)^2}} = \frac{170}{\sqrt{200 + (754 - 199)}} = 0.288A$$