Name: ______________________________

This is an open book and open note test. 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) Electric charges can be found

   ☑ in discrete levels. ○ in a spectrum of levels ○ together in pairs, never separate.

2. (2 points) The electric force and the magnetic force are both proportional to

   ○ $1/r$
   ☑ $1/r^2$
   ○ $1/r^3$
   ○ r

3. (2 points) Gauss's Law doesn't work for magnetic fields because

   ☑ The poles of a magnetic field are always found together.
   ○ The North pole of a magnetic field has more charge than the South pole.
   ○ The South pole of a magnetic field has more charge than the North pole.

4. (2 points) The electric field is

   ○ Proportional to the charge around a wire loop.
   ○ Proportional to $1/r$.
   ○ Proportional to the current divided by distance from the current.
   ☑ Proportional to the force a test charge would feel at that point.

5. (2 points) The electric potential energy is a [ ] and the electric force is a [ ].

   ☑ scalar/vector ○ vector/scalar ○ scalar/scalar ○ vector/vector

6. (2 points) A real-world wire

   ○ Always has resistance.
   ☑ Always has resistance except for very special super-conducting wires which we might not have covered in class but should have read about in the book. We did read each chapter as we went along, right?
   ○ Only has resistance if you put a resistor on it.
   ○ Has internal EMF source.

7. (2 points) A capacitor and a resistor wired in a DC circuit will cause the current to oscillate.
   - [x] False ○ True

8. (2 points) An inductor and a capacitor wired in a DC circuit will cause the current to oscillate.
   - ○ False [x] True

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

   - ○ The input of a circuit junction is equal to the voltage across the junction.
   - [x] 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) The benefit of AC electricity over DC electricity is that

    - ○ DC can be transmitted at lower voltage and so is not useful.
    - ○ AC can be transmitted at higher voltage and so is more useful.
    - [x] AC is cheaper to transmit than DC.
    - ○ AC is safer overall

11. (2 points) We learned in class that $1/\sqrt{\mu_0\epsilon_0}$ is equal to
    - [x] The speed of light ○ The Inductance ○ The Omega Constant ○ The speed of sound

Problems

12. An average of 120 kW of electrical power is sent to a small town from a power plant 10 km away. The transmission lines have a total resistance of 0.40 Ω. Calculate the power loss if the power is transmitted at $240V$ (which is ideal for DC) and $24,000V$ (which is doable for AC power only). Explain why your results support the claim that AC power is more efficient. *Hint: Relate current to power, and then current to power loss.*

DC

$$I_{rms} = \frac{P_{avg}}{\Delta V_{rms}} = \frac{120{,}000\,W}{240\,V} = 500\,A$$

$$P_{lost} = I_{rms}^2 R = (500A)^2(0.40\Omega) = 100{,}000\,W$$

Loses most power in transmission.

AC

$$I_{rms} = \frac{P_{avg}}{\Delta V_{rms}} = \frac{120{,}000\,W}{24{,}000\,V} = 5\,A$$

$$P_{lost} = I_{rms}^2 R = (5A)^2(0.40\Omega) = 10\,W$$

Loses little power in transmission.

13. A coil has a resistance $R = 1.00\Omega$ and an inductance of $0.300H$. Determine the current in the coil if 120 V DC is applied to it; and if 120-V AC is applied to it with frequency 60.00 Hz.

DC $I = \frac{V}{R} = \frac{120V}{1\Omega} = 120A$

AC $X_L = 2\pi f L = (6.28)(60\frac{1}{s})(0.3H) = 113\Omega$

$I_{rms} = \frac{V_{rms}}{X_L} = \frac{120V}{113\Omega} = 1.06A$

14. A capacitor is wired up to an AC voltage source. What is the rms current in the circuit if $C = 1.0\mu F$ and $V_{rms} = 120V$ at 60 Hz? What if we increase the frequency to 6.0×10^5 Hz?

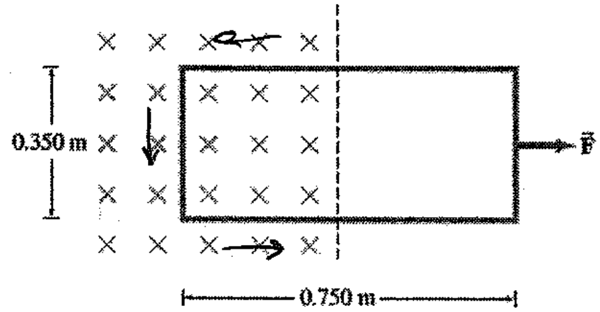
$I_{rms} = \frac{V_{rms}}{X_C} = \frac{120V}{2.7\times10^3\Omega} = 44\times10^{-3}A$

$X_C = \frac{1}{2\pi f C} = \frac{1}{\omega C} = 2.7k\Omega$

@ $f = 6.0\times10^5 Hz \longrightarrow$

$I_{rms} = \frac{120V}{2\pi(6.0\times10^5)(1\times10^{-6}F)}$

$= 440A$



15. In the figure above we see a single rectangular loop of wire with given dimensions situated inside a region of uniform magnetic field of 0.550 T. The total resistance of the loop is 0.230 Ω. Calculate the force required to pull the loop from the field (to the right) at a constant velocity of 3.40 m/s. Ignore gravity.

Flux = $B \cdot A > \Phi_B$

$-\frac{d\Phi}{dt} = \mathcal{E} = B\frac{dA}{dt} = B\frac{d}{dt}(0.350(0.750 - x))$

$\mathcal{E} = B(0.350)v$

$= 0.550\,T(0.350\,m)(3.40\,\frac{m}{s})$

$= 0.6545\,V$

$F = qvB = I\ell B$

$= 2.8A(0.350)(0.550\,T)$

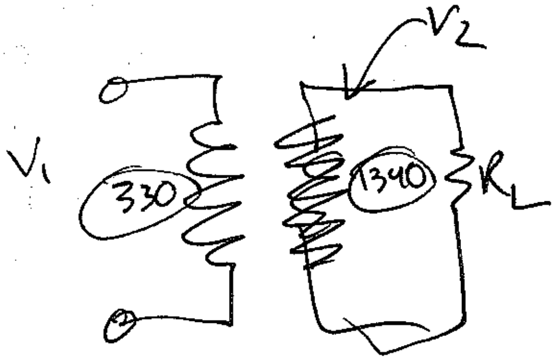
$= 0.55\,N$

$V = IR$

$I = \frac{\mathcal{E}}{R} = \frac{0.6545\,V}{0.230\,\Omega}$

$= 2.8A$

16. A transformer has 330 primary turns and 1340 secondary turns. The input voltage is 120 V and the output current is 15.0 A. What are the output voltage and input current?



$V_2 = V_1 \left(\frac{1340}{330}\right)$

$V_2 = 120V\left(\frac{1340}{330}\right)$

$= 487.3\ V$

output

$V = I R_L$

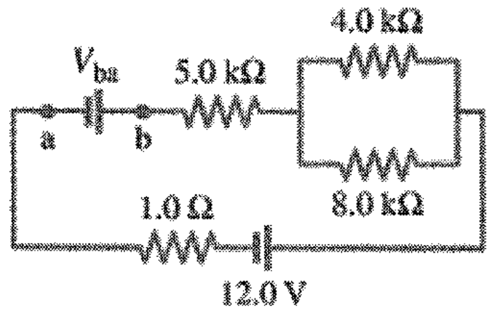
$487.3V = 15A\ R_L \rightarrow R_L = 32.5\ \Omega$

33.42

$I_1 \Delta V_1 = I_2 \Delta V_2$

$I_1(120) = 15(487.3)$

$I_1 = 60.9\ A$



17. The current through the 4.0 kΩ resistor in the above circuit is 3.50 mA. What is the terminal voltage V_{ba} of the unknown battery V_{ba}? Assume that the current direction is to the right. *Bonus: What if we were to assume the current direction is to the left?* Hint: Use the loop rule (also known as Kirchhoff's rule).

To the right →

$V = IR = (3.5\times10^{-3}A)(4000\Omega) = 14V$

in parallel with the 8 kΩ so that

$14V = I(8\times10^{3}\Omega) \rightarrow I = 1.75\times10^{-3}A$

Total current = $3.5\times10^{-3}A + 1.75\times10^{-3}A$

$= 5.25\times10^{-3}A \rightarrow$

$V_{ab} + (-5000\Omega)I_{tot} - 14V - 12V - 1\Omega(I_{tot})$

$V_{ab} = 26V + 5001\Omega(5.25\times10^{-3}A) = 52.3V$

To the left

$V_{ab} + (5000\Omega)I_{tot} + 14V - 12V + 1.0\Omega I_{tot} \rightarrow$

$V_{ab} = -2V - 5001\Omega(5.25\times10^{-3}A) = -28.3V$

18. If a charged capactior $C = 35\mu F$ is connected to resistance $R = 120\Omega$, how much time will elapse until the charge across the capacitor falls to 10% of its original value? *Hint: Chapter 28 and you are solving for t and using 0.10 Q = ?*

$$q(t) = Q e^{-t/RC}$$

$$0.10 Q = Q e^{-t/RC}$$

$$0.10 = e^{-t/RC} = e^{-t/120(35\times10^{-6})}$$

$$\ln(0.10) = \frac{-t}{120(35\times10^{-6})}$$

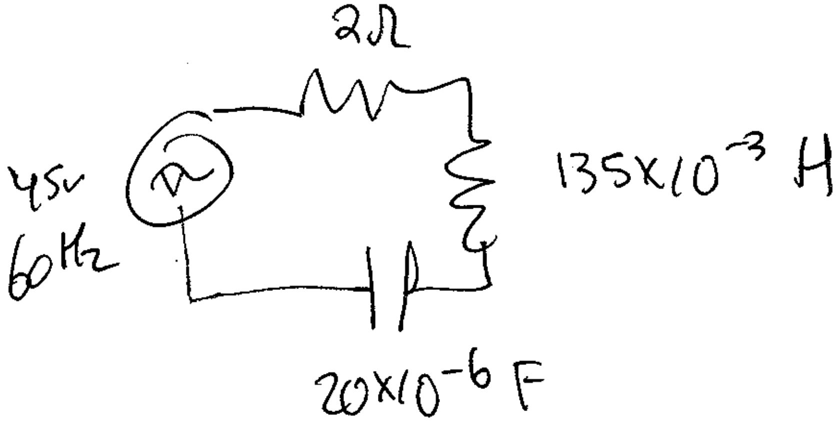
$$t = +0.00967\,s$$

19. For a 120 V rms 60 Hz voltage, an rms current of 70 mA passing through the human body for 1.0 s could be lethal. What must the impedance of the body be for this to occur?

$$I_{rms} = \frac{\Delta V}{Z}$$

$$70\times10^{-3} A = \frac{120}{Z} \rightarrow Z = 1714\,\Omega$$

20. A 135-mH inductor with 2.0 Ω resistance is connected in series to a 20 μF capacitor and a 60 Hz 45 Volt source. Calculate the rms current and the phase angle.



$$X_L = \omega L = 2\pi(60\,\text{Hz})\,135\times10^{-3}\,\text{H} = 50.9\,\Omega$$

$$X_C = \frac{1}{\omega C} = \frac{1}{2\pi(60\,\text{Hz})(20\times10^{-6}\,\text{F})} = 132.63\,\Omega$$

$$Z = \sqrt{R^2 + (X_L - X_C)^2}$$

$$= \sqrt{2^2 + (50.9 - 132.63)^2}$$

$$= 81.754\,\Omega$$

$$I_{max} = \frac{\Delta V_{max}}{Z} = \frac{45\,\text{V}}{81.754\,\Omega} = 0.55\,\text{A}$$

$$\phi = \tan^{-1}\left(\frac{50.9 - 132.63}{2}\right) = -1.54\ \text{rads}$$

or -89°