Sec. 5 - Power. Kirchhoff's Laws.

Read: Ch 26, sec.6; Ch. 27, sec. 1, 3 & 5.

A. Find the currents $I_1$, $I_2$, and $I_3$ in the figure shown.
   ans: 141 mA, 915 mA, 774 mA

B. 1. (6 points) Find the value of $R$ in the circuit shown.
   ans: 9.00 Ω

2. (4) A 1500 W electric heater, a 750 W toaster, and a 1000 W electric grill are all connected to the same 120 V circuit. (a) How much current does each draw? (b) Is a 25 A circuit breaker sufficient in this situation? (Show how you got your answer; a "yes" or "no" that looks like a guess will not get full credit.)
   ans: 12.5 A, 6.25 A, 8.33 A, No

C. The ammeter reads 2.00 A. Find $I_1$, $I_2$, and $E$.
   ans: .714 A, 1.29 A, 12.6 V

D. 1. (2 pts) Two light bulbs both operate from 110 V, but one has a power rating of 25 W and the other of 100 W. Which bulb has the higher resistance? Which bulb carries the greater current?
   2. (8) For the circuit shown, calculate the current in the 2.00 Ω resistor.
      ans: 909 mA

E. 1. (2 pts) Children are warned not to fly kites around high voltage power lines, yet birds sit on them without harm. Explain why the wires are dangerous for children but not birds.
   2. (2 pts) A student uses the loop rule to write this equation: $3 V - (5 \Omega)(I_1) + 7 V - I_2 = 0$. Without even seeing the circuit, how can you tell that this is incorrect?
   3. (6) In a hydroelectric installation, a turbine delivers 1500 hp to a generator, which in turn converts 80.0% of the mechanical energy into electrical energy. Under these conditions, what current does the generator deliver at a terminal potential difference of 2000 V?
      ans: 448 A
F. 1. (1 point) Under what condition does the potential difference across the terminals of a battery equal its emf? (Note that any battery has at least a little internal resistance.)

2. (1) Someone is "frozen" to a live high voltage wire that is not in some device you can just unplug. How would you try to save this person without endangering your own life?

3. (8) Find the charge on the capacitor. (Notice that since the space between the plates does not conduct, a steady current can’t flow through a capacitor.)
   \[ \text{ans: } 6.00 \mu C \]

Sec. 6 - Continuous Charge Distributions

Read: Ch 23 sec 1.

A. A uniformly charged negative rod is bent into a semicircle (\( \theta \) runs from -\( \pi/2 \) to +\( \pi/2 \)) of radius 4.5 cm. Each infinitesimal piece of the rod, as shown, has a charge of \( \left| dq \right| = 2.4 \times 10^{-6} \, \text{d} \theta \) coulomb. Find the magnitude and direction of the electric field at C, the center of the semicircle.
   \[ \text{ans: } -2.13 \times 10^7 \, \hat{i} \, \text{V/m} \]

B. 1. (1 pt.) A uniformly charged rod lies along the x axis. Its total charge is Q and its total length is L. What is \( dq \), the charge of a small piece of it, in terms of dx, the length of the piece?

2. (9) A charge Q is uniformly distributed along this rod.
   The charge of a small piece, as shown, is \( dq = \frac{Q}{2ab} \, r^2 \, d\theta \).
   Find the electric field vector at a point which is a distance \( b \) above the center.
   \[ \text{ans: } E = \frac{1}{4\pi\varepsilon_0} \frac{Q}{bR} \, \hat{j} \]

C. 1. (1 pt.) A uniformly charged rod of length L and total charge Q is bent into a semicircle of radius R as shown with problem A. The length of the small piece which lies within the angle \( d\theta \) is Rd\( \theta \). In terms of Q, L, R and \( d\theta \), what is the charge of the small piece?
2. (9) A thin positively charged rod of length $2a$ lies a distance $a$ from the origin, as shown. Its charge per unit length, $\lambda$, varies as $\lambda = \lambda_0/x$ (where $\lambda_0$ is a constant), which means that the charge on a piece of the rod $dx$ long is $dq = (\lambda_0 dx)/x$. Find the electric field vector at the origin.

ans: $\vec{E} = \frac{-1}{9\pi\varepsilon_0 a^2} \hat{i}$

D. A line of charge starts at $x = +x_0$ and extends along the $x$ axis to positive infinity. If the linear charge density is $\lambda = \lambda_0 x_0/x$, where $\lambda_0$ and $x_0$ are constants, determine the electric field vector at the origin.

ans: $\vec{E} = \frac{-1}{8\pi\varepsilon_0 x_0} \hat{i}$

E. A thin charged rod is bent into a circle of radius $R$ as shown. Its charge per unit length, $\lambda$, varies as $\lambda = \lambda_0 \cos \theta$ (where $\lambda_0$ is a constant), which means that the charge on a piece of the rod within an angle $d\theta$ is $dq = (\lambda_0 \cos \theta)(R d\theta)$. Find the electric field vector at the origin.

ans: $\vec{E} = \frac{-\lambda_0}{4\varepsilon_0 R} \hat{i}$

F. A line of charge starts at the origin and extends along the $x$ axis to positive infinity. It has a uniform linear charge density, $\lambda$. Set up an expression for the electric field vector, $\vec{E}$, a distance $a$ above its end, in terms of $x$, $a$, $\lambda$ and fundamental constants. It is not necessary to evaluate the integrals in this expression.

Hints: Notice from the diagram that $\sin \theta = a/r$ and $\cos \theta = x/r$.

\[
\frac{\lambda}{4\pi\varepsilon_0} \left( \frac{x}{x^2 + a^2} \right)^{3/2} + \frac{a j}{x^2 + a^2} \frac{dx}{(x^2 + a^2)^{3/2}} \right) \]

ans: $\frac{\lambda}{4\pi\varepsilon_0} \left( \frac{x}{x^2 + a^2} \right)^{3/2} + \frac{a j}{x^2 + a^2} \frac{dx}{(x^2 + a^2)^{3/2}}$

Sec. 7 - Magnetic Forces

Read: Ch. 28: start – sec. 5. (Just skim sec. 3.)

A. 1. (2 pts) An electron is moving in the $+x$ direction in a magnetic field which also points in the $+x$ direction. Does it feel a force? If so, in what direction?

2. (8) The horizontal conductor shown has a mass per unit length of $0.0400 \text{ kg/m}$, and is in a $3.60 \text{ T}$ magnetic field which points into the page. What current must exist in the conductor for the tension in the supporting wires to be zero? What is the direction of the current?

ans: $0.109 \text{ amp toward the right}$
B. 1. (2 pts) Like magnetic poles repel. Explain, then, why the "north" pole of a magnet is attracted to the geographic North Pole of the Earth.

2. (8) A positive ion with a mass of $3.20 \times 10^{-26}$ kg and a charge of $1.60 \times 10^{-19}$ C is accelerated through a potential difference of 833 V, and then enters a .920 T magnetic field. The ion is moving perpendicular to the field's direction. Calculate the radius of the ion's path in the field.

\[
\text{ans: } 1.98 \text{ cm}
\]

C. 1. (2 pts) Consider a copper wire which has a current in it. (a) Does it feel a force if perpendicular to an electric field? (b) Does it feel a force if perpendicular to a magnetic field?

2. (8) A proton moves with velocity $1.30 \times 10^5 \hat{i}$ m/s through an electromagnetic field, as shown. If $\vec{E} = 9.70 \times 10^4 \hat{i}$ v/m and $\vec{B} = -0.370 \hat{k}$ tesla, find the magnitude of the proton's acceleration.

\[
\text{ans. } 1.04 \times 10^{-13} \text{ m/s}^2
\]

D. 1. (2 pts) Consider a beam of electrons in a vacuum tube. (a) Does it feel a force if perpendicular to an electric field? (b) Does it feel a force if perpendicular to a magnetic field?

2. (8) The magnetic field over a certain region is given by $\vec{B} = (4.00 \hat{i} - 11.0 \hat{j})$ T. An electron moves in this field with a velocity $\vec{v} = (-2.00 \hat{i} + 3.00 \hat{j} - 7.00 \hat{k})$ m/s. Find the force on the electron, in unit vector notation.

\[
\text{ans: } (12.3 \hat{i} + 4.48 \hat{j} - 1.60 \hat{k}) \times 10^{-18} \text{ N}
\]

E. 1. (2 points) Consider a stationary charged plastic ball.

(a) Does it feel a force in an electric field? (b) Does it feel a force in a magnetic field?

2. (1) A beam of electrons in a vacuum is an example of an electric current, so a magnetic field exists around it. If you could move as fast as the electrons so they were stationary relative to you, would you still find a magnetic field around them?

3. (7) A current of 17.0 mA is maintained in a single circular loop of 2.00 m circumference. An external magnetic field of .800 T is directed parallel to the plane of the loop. How large is

a. the loop's magnetic moment?

b. the torque exerted on the loop by the magnetic field?

\[
\text{ans: } 5.41 \text{ mA-m}^2, 4.33 \text{ mN-m}
\]

F. 1. (2 pts) A proton moving horizontally enters a region where a uniform magnetic field is directed perpendicular to the proton's velocity.

a. What kind of curve is the shape of the proton's path through the field?
b. State one way that the particle's path would be different, under the same circumstances, if it was an electron instead.

2. (8) A positive charge \( q = 3.20 \times 10^{-19} \text{ C} \) moves with a velocity \( \vec{v} = 2.00 \hat{i} + 3.00 \hat{j} - 1.00 \hat{k} \text{ m/s} \) through a region where both a uniform magnetic field and a uniform electric field exist. \( \vec{B} = 2.00 \hat{i} + 4.00 \hat{j} + 1.00 \hat{k} \text{ T} \) and \( \vec{E} = 4.00 \hat{i} - 1.00 \hat{j} - 2.00 \hat{k} \text{ V/m} \). What is the total force on the charge in unit-vector notation?

\[ \text{ans: } 3.52 \hat{i} - 1.60 \hat{j} \text{ aN} \]

Sec. 8 - Magnetic Fields/ Ampere's Law

Read: Ch. 29, sec. 2 – 4

A. This shows part of a thin copper tube’s cross section. Each 1.00 cm of its circumference carries 1.70 A out of the page, as indicated by the dots.

a. What is \( B \) a small distance from the tube, inside it?

b. What is \( B \) a small distance from the tube, outside it? (Hint: the 1.00 cm long dashed loop is for this part.)

c. Find the force vector on the electron located in the upper right part of the picture. It is moving at \( 2.50 \times 10^6 \text{ m/s} \).

(Show enough detail that I can tell you didn’t make two sign errors that cancel each other, giving the right answer.)

\[ \text{ans: } 0, 2.14 \times 10^{-4} \text{ T}, -8.57 \times 10^{-17} \hat{k} \text{ N} \]

B. 1. (2 pts) Consider a beam of electrons in a vacuum tube.

(a) Does it create an electric field?  (b) Does it create a magnetic field?

2. (8) Four long parallel conductors carry equal currents of 5.00 A perpendicular to the plane of the page. A cross indicates a current into the page; a dot indicates a current out of the page. Find the magnitude and direction of the magnetic field at point P, the center of the square.

\[ \text{ans: } 20 \mu \text{T toward top of page} \]

C. A long straight wire of radius \( R \) carries a steady current \( I \), uniformly distributed across its cross section.  (a) To find the magnetic field at a point inside a distance \( r \) from the center \( (r < R) \),

i. Make a sketch showing the path you will use.

ii. Find an expression for the current passing through this path.

iii. Show how to find an expression for \( B \) from your answer to (ii).

(b) Repeat for a point outside \( (r \geq R) \).

\[ \text{ans: } B = \mu_0 I r / (2\pi R^2), \quad B = \mu_0 I / (2\pi r) \]
D. 1. (2 pts) Consider a copper wire which has a current in it.
   a. Does it create an electric field?
   b. Does it create a magnetic field?

2. (8) A long sheet of aluminum foil, \( L = 0.800 \) m wide in the \( y \) direction, lies in the \( yz \) plane. It carries a uniformly distributed 11.0 A, flowing in the \( +z \) direction. How large is \( B \) near this sheet? (“Near” means the distance to the sheet is much less than to any of its edges.) Hint: In working with Ampere’s law, it will be useful to consider the current per unit of vertical length.
   \[ \text{ans: } 8.64 \, \mu T \]

E. The cross sectional view of a coaxial cable is shown. The center conductor is surrounded by a rubber layer, which is surrounded by an outer conductor, which is surrounded by another rubber layer. The current in the inner conductor is 1.00 A out of the page, and the current in the outer conductor is 3.00 A into the page. Find the magnitude and direction of the magnetic field at (a) point a, and (b) point b.
   \[ \text{ans: } 200 \, \mu T \text{ toward top of page, } 133 \, \mu T \text{ toward bottom of page} \]

F. 1. (2 pts) A hollow copper tube carries a current along its length.
   a. How can you tell that \( B = 0 \) inside the tube?
   b. Does \( B \) also equal zero outside the tube?

2. (8) A beam of electrons is moving at \( 2.00 \times 10^7 \) m/s perpendicular to the field inside a 5000 turn solenoid which is 2.00 m long. If the beam's path is to have a radius of 6.00 cm, what should the current in the solenoid be?
   \[ \text{ans: } 0.603 \, \text{A} \]

Sec. 9 - Induction. Maxwell's Equations.

Read: Ch 29 sec 5; Ch 30, sec 1, 4 and just skim sec. 5; Ch. 33 sec. 1 & 2.

A 1. (2.5 pts) a. Do Maxwell's equations allow for the existence of magnetic monopoles?
   b. Which of the equations does your answer follow from?
   c. How would this equation be different if the answer to (a) was different?

2. (7.5) A single wire loop enclosing 8.00 cm\(^2\) lies in a plane which is perpendicular to an external magnetic field. (That is, the field comes from some external source; it is not produced by the loop.) The field increases uniformly from \( 0.500 \) T to \( 2.50 \) T in 1.00 s. What is the current in the loop if its resistance is \( 2.00 \) \( \Omega \)?
   \[ \text{ans: } 0.800 \, \text{mA} \]
B. 1. (1 point) A loop of wire encloses an area of 1.00 m$^2$. $\vec{B}$ is parallel to the axis of this loop and the same everywhere over the 1.00 m$^2$ at a given instant. As time passes, it increases according to $B = t^2$. Explain why, even though $\Phi = \int \vec{B} \cdot d\vec{A}$, the flux through this loop is $t^2$ not $\frac{1}{3} t^3$.

2. (2) There are two ways to make an electric field: 1) An $\vec{E}$ field is found around a charge and 2) An $\vec{E}$ field is induced by a changing $\vec{B}$ field. Make a similar list of the way(s) to make a magnetic field.

3. (7) A 30 turn circular coil of radius 4.00 cm is placed in a magnetic field directed perpendicular to the plane of the coil. The magnitude of the magnetic field varies in time according to the expression $B = .0100t + .0400t^2$, where $t$ is in seconds and $B$ is in teslas. What is the induced emf in the coil at $t = 5.00$ s?
   ans: 61.8 mV

C. A stripe of gold paint with a resistance of 2.00 x $10^{-3}$ ohm goes around the equator of a balloon. The balloon's axis is parallel to the earth's magnetic field, which has a magnitude of 1.10 x $10^{-4}$ Tesla here. As the balloon deflates, its radius decreases according to $r = 5.00 - 10.0t$ where $r$ is in cm and $t$ is in seconds. Find the current in the stripe at $t = .370$ s.
   ans: 4.49 x $10^{-4}$ A

D. 1. (2 pts) Will a transformer operate if a continuously connected battery is used for the input voltage across the primary? Explain.

2. (8) There is a uniform magnetic field of (.350)$\hat{i}$ T throughout the region shown. In this field, a loop of wire spins around the z axis, making its area vector move according to $\vec{A} = (.220 \text{ m}^2)[\cos(400t) \hat{i} + \sin(400t) \hat{j}]$, where $t$ is in seconds. Find the emf induced in this loop at $t = .0180$ s.
   ans: 24.4 V

E. 1. (2 pts) The field through a flat coil from an approaching magnet is increasing according to $B = t^2$. You are asked for the current induced in the coil. Explain why solving $t^2 = \frac{N \mu_0 I R^2}{2 (R^2 + x^2)^{3/2}}$ for $I$ is wrong.

2. (8) The picture shows the magnetic field inside a coil of radius $R = 2.50$ cm. The field is directed into the page and changes according to $B = .0300t^2 + 1.40$, where $B$ is in teslas and $t$ is in seconds. What is the magnitude of the electric field at point P if $t = 3.00$ s and $r = 2.00$ cm?
   ans: 1.80 mV/m

F. In SI units, the voltage applied to the parallel plate capacitor shown is given by $V = 25.0 \sin 4000t$. The plates are .00200 m apart, and have an area of .0201 m$^2$. In these units, find the following as a function of time:
   (a) the electric flux between the plates, $\Phi_E$. 

(b) the induced magnetic field, \( B \), .08 m from the center of the plates. (Put your answer to part a into the Ampere-Maxwell equation. Assume all of the capacitor’s electric flux is directly between the plates.)

\[
\text{ans: } 251 \sin 4000t, \ 2.22 \times 10^{-11} \cos 4000t
\]

Sec. 10 – More Induction. \( E \) and \( B \) fields in Matter.

Read: Ch. 25, sec 5; Ch 29 sec 6; Ch 30 sec 3; Ch. 31 sec 1 & 4

A. 1. (2 pts) Imagine that a bar magnet is above the page, south pole down and falling toward the loop of wire shown. Does current flow around the loop clockwise or counterclockwise?

2. (8) An inductance \( L \) is in series with a resistance \( R \). When the current through them is 2.0 A and increasing at a rate of 1.0 A/s, the total potential difference across the pair of them is 8.0 V. However, when the current through them is 2.0 A decreasing at 1.0 A/s, the total potential difference is 4.0 V. Find the values of \( L \) and \( R \).

\[
\text{ans: } L = 2 \ \text{H}, \ R = 3 \ \Omega
\]

B. 1. (2 points) In the side of this coil which faces you, does current flow from the bottom toward the top, or top to bottom?

\[
\text{ans: top to bottom}
\]

2. (3 pts) A parallel plate capacitor with air between its plates is charged to 31.5 volts. The capacitor is then isolated from the charging source, and the volume between its plates filled with paper. Determine the new potential difference across the capacitor.

\[
\text{ans: } 8.51 \ \text{V}
\]

3. (5) The current in a 90.0 mH inductor changes with time as \( I = t^2 - 6.00t \) (in SI units).

a. Find the magnitude of the induced emf at \( t = 4.00 \) s.

\[
\text{ans: } 180 \ \text{mV}, \ 3.00 \ \text{s}
\]

C. 1. (2 points) What is the direction of the induced current in resistor \( R \) when the current \( I \) decreases rapidly to zero? (Toward the left or the right?)

\[
\text{ans: right}
\]

2. (2.5 pts) An emf of 96.0 mV is induced in a coil when the current in a nearby coil is increasing at the rate of 1.20 A/s. What is the mutual inductance of the two coils?

\[
\text{ans: } 80.0 \ \text{mH}
\]

3. (5.5) A solenoid 30.0 cm long with 1500 turns is wound around a material with a permeability of \( 4.45 \times 10^{-5} \) N/A\(^2\). This coil carries 1.75 A. At a point inside the material, what are

a. \( B \), the magnitude of the total magnetic field,

b. \( B_0 \), what the field there would be if the coil was empty and
c. the contribution to B from the material’s magnetization.
ans: .389 T, .0110 T, .378 T

D. 1. (2 pts) The centers of two circular loops are separated by a fixed distance. For what relative orientation of the loops is their mutual inductance (a) a maximum? (b) a minimum?

2. (8) A parallel plate capacitor has a plate area of 0.640 cm². When the plates are in a vacuum, the capacitance of the device is 4.9 pF. (a) Calculate the value of the capacitance if the space between the plates is filled with nylon. (b) What is the maximum potential difference that can be applied to the plates without causing dielectric breakdown?
ans: 16.7 pF, 1.62 kV

For parts of quizzes E and F, refer back to section 9.

E. 1. (2 pts) Why does hitting a magnet with a hammer reduce its magnetization?

2. (8) The magnetic field inside this solenoid varies according to B = (.0750 T)cos(ωt). For the induced electric field 8.00 cm from the center to have an amplitude of E_{max} = 15.0 V/m, what angular frequency, ω, is needed?
ans: 5000 rad/s

F. 1. (3 pts) What is the difference between ferromagnetic, paramagnetic and diamagnetic substances?

2. (7) A circular loop of wire has a radius of 7.00 cm and a resistance of .0110 Ω. This loop is inside a solenoid, with the loop’s axis parallel to the solenoid’s. The field from the solenoid decreases steadily from .500 T at t = 1.00 s to .150 T at t = 4.00 s. What is the current in the loop during this interval?
ans: .163 A

Sec. 11 - RL, RC, & LC Circuits/Electric & Magnetic Energy.

Read: Ch. 25 sec. 4; Ch. 27 sec. 4; Ch. 31 sec. 2, 3, & 5

A. The 7.00 mH inductor is a coil in a vacuum with 2.30 x 10^{-5} m³ inside it. It is long enough to consider its field uniform. When the switch is closed at t = 0, the capacitor has 11.0 V between its plates.
   a. How much energy is stored in the capacitor at t = 0?
After the switch is closed, charge flows from the capacitor and soon V = 0.
Assuming no energy is lost from the circuit, what are the following when V = 0?
   b. The current in the circuit,
   c. the energy density (energy per unit volume) of the coil's magnetic field,
   d. B in the coil.
ans: 151 μJ, .208 A, 6.58 J/m³, .00407 T

B. 1. (2 pts) If the resistance of the wires of an LC circuit was not zero, would the oscillations persist indefinitely? Explain.

2. (8) A capacitor in an RC circuit is charged to 60.0% of its maximum value in .900 second. What is the time constant of the circuit? 
  ans: .982 s

C. The resistor in an RL circuit is replaced with a piece of nonohmic material for which \( V = k(I^2) \), where \( k \) is a constant, instead of being equal to IR. The current in this circuit is \( I_0 \) until \( t = 0 \), when the battery is suddenly switched out of the circuit. \( I = I_0 e^{-t/\tau} \) does not apply in this case. Find the expression for how \( I \) decays with time which does apply.
  ans: \( I = I_0 L/(L + I_0 kt) \)

D. 1. (1 pt) When the circuit in the next problem reaches its final, steady state, what is the inductance of the coil?

2. (9) If \( E = 6.00 \text{ V}, L = 8.00 \text{ mH}, \) and \( R = 4.00 \text{ Ω}, \)
  a. What is the inductive time constant of this circuit?
  b. Calculate the current 250 μs after the switch is closed.
  c. What is the value of the final, steady-state current?
  ans: 2.00 ms, .176 A, 1.50 A

E. The LC circuit consists of a 3.30 H inductor and a 840 pF capacitor, initially carrying a 105 μC charge. At \( t = 0 \), the switch is closed. Compute the following quantities at \( t = 2.00 \) ms: (a) the total energy in the circuit, (b) the energy stored in the capacitor,
  ans: 6.56 J, 6.04 J

F. 1. (1 pt) As the voltage increases across a capacitor being charged in an RC circuit, does the current flowing into it increase, decrease, or stay the same?

2. (4) The energy which can be stored in an electric field in matter is limited by dielectric breakdown. What is the maximum energy density for Bakelite?
  ans: \( 1.25 \times 10^4 \text{ J/m}^3 \)

3. (5) A 5.0 mH coil has a resistance of 7.5 Ω. At one particular instant, the current through it is .30 A, and increasing at a rate of 600 A/s. Find the voltage across the coil at this instant.
  ans: 5.25 V

Sec. 12 - A.C. Circuits
A. Consider a series RLC circuit for which $R = 200 \, \Omega$, $L = 600 \, \text{mH}$, and $C = 26.5 \, \mu\text{F}$. The applied voltage has an amplitude of 50.0 V, and a frequency of 60.0 Hz. Find
(a) the amplitude of the current,
(b) the phase angle between the current and the applied voltage,
(c) the amplitude of voltage across the inductor,
(d) the phase angle between the current and the voltage across the inductor.

ans: 211 mA, $v$ leads by 32.2°, 47.7 V, $v$ leads by 90.0°

B. 1. (4½ points) An RLC circuit is used in a radio to tune in a station broadcasting at 99.7 MHz. The resistance in the circuit is 12.0 Ω, and the inductance is 1.40 μH. What capacitance should be used?

ans: 1.82 pF

2. (5½ points) The rms output voltage of an AC generator is 200 V, and the operating frequency is 100 Hz. Write the equation giving the output voltage as a function of time. Assume the phase angle is 0.

ans: $\Delta v = (283 \, \text{V})\sin[(628 \, \text{s}^{-1}) \, t]$

C. 1. (3) A step-up transformer is designed to have an output voltage of 2200 V when the primary is connected across a 110 V source. (a) If there are 80 turns on the primary winding, how many turns are required on the secondary? (b) If a resistor across the secondary draws a current of 1.50 A, what is the current in the primary under ideal conditions?

ans: 1600, 30 A

2. (7) A resistor, $R$, is in series with a capacitor, $C$. In SI units, the current in them is $I = 1.70 \sin(377t)$ and the voltage across the pair is $\Delta v = 56.0 \sin(377t - 0.800 \, \text{rad})$. Find (a) the group’s impedance, (b) $R$ and (c) $C$.

ans: 32.9 Ω, 22.9 Ω, 112 μF

D. 1. (1 pt) What is the advantage of transmitting power at high voltages?

2. (1 pt) What is the impedance of an RLC circuit at the resonance frequency?

3. (8) An RMS current of 4.5 A flows through a 3.0 mH coil when it is connected to a 50 V (RMS), 400 Hz AC source. What is the coil's internal resistance?

ans: 8.16 Ω

E. 1. (2 pts) a. In a series RLC circuit, what is the possible range of values for the phase angle?
b. What is the phase angle when the inductive reactance equals the capacitive reactance?

2. (8) All values given or asked for are RMS. A light bulb is connected in series with an inductor across a household outlet (120 V, 60 Hz). If the bulb consumes 60 watts, and the current is .75 A, find (a) the voltage across the bulb, (b) the voltage across the inductor.
ans: 80 V, 89.4 V

F. 1. (1.5 point) An AC ammeter reads an effective current of 1.00 amps. What is the value of A on this graph?

2. (3 pts) a. i. In words, what causes capacitive reactance? That is, what opposes the flow of current into a capacitor?
   ii. How does this explain the fact that capacitive reactance decreases with increasing frequency?

   b. i. In words, what causes inductive reactance? That is, what opposes the buildup of current in a coil?
   ii. How does this explain the fact that inductive reactance increases with increasing frequency?

3. (5.5) A series RLC circuit has a resistance of 45.0 Ω and an impedance of 75.0 Ω. What average power is delivered to this circuit when $\Delta V_{rms} = 210$ V?
   ans: 353 W

Sec. 13 - The First Law/Thermodynamic Processes

Read: Ch 19, sec. 4 & 5; Ch. 20, sec 2 & 4

A. One mole of an ideal monatomic gas, initially at 300 K and 1.00 atmosphere is compressed adiabatically to one fourth of its initial volume. Find its final pressure and temperature.
   ans: 10.1 atm, 759 K

B. 1. (2 pts) Give an example of each of the following situations:
   a. Heat is added to an object, its internal energy increases and its temperature increases. (sample answer: Hold a piece of metal over a flame.)
   b. Heat is added, its internal energy increases, and temperature does not increase.

   2. (8) In a constant volume process, 209 J of energy is transferred by heat to 1.00 mole of an ideal monatomic gas initially at 300 K. Find (a) the increase in the internal energy of the gas, (b) the work done on it, and (c) its final temperature.
   ans. 209 J, 0, 317 K

C. 2.00 moles of helium gas, initially at 300 K and .400 atm is compressed isothermally to 1.20 atm. Find: (a) the final volume of the gas, (b) the work done on the gas, and (c) the energy transferred by heat.
   ans: .0410 m³, 5.48 kJ, -5.48 kJ

D. 1. (2 pts) Give an example of each of the following situations:
   a. No heat is added to an object, its internal energy increases, and its temperature increases.
   b. Work is done on an object, its internal energy does not increase, and its temperature does not
2. (8) A sample of ideal gas expands from its original volume of 1.00 m$^3$ to a final volume of 2.00 m$^3$ in a quasi-static process for which $P = \alpha V^2$, with $\alpha = 5.00$ atm/m$^6$, as shown. How much work was done on the expanding gas?
   
   ans: $-1.18$ MJ (1.18 MJ done by the gas)

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E. 1. (2 pts) As an ideal gas expands, it does 100 J of work. What is $\Delta E_{\text{int}}$ (the increase in internal energy) if the expansion is
   
   a. adiabatic?
   b. isothermal?

2. (8) A gas expands from point I to F. Calculate the work done on the gas if the change is made along (a) path IF, (b) path IAF.
   
   ans: $-506$ J, $-203$ J

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F. At a constant pressure, 1.00 mole of hydrogen gas is heated from 300 K to 420 K. Calculate (a) the energy transferred by heat to the gas, (b) the increase in its internal energy, and (c) the work done on the gas.
   
   ans: 3.46 kJ, 2.45 kJ, $-1.01$ kJ

Sec. 14 - Heat Engines & The 2nd Law of Thermodynamics

Read: Ch. 21: sec. 1 – 4, skim sec. 6, read sec 7 & 8.

A. 1. (1 point) Is it possible to construct a heat engine that creates no thermal pollution?

2. (9) Calculate the change in entropy of 250 grams of water heated slowly from 20.0 °C to 80.0°C. (Hint: Note that $dQ = m c dT$. For water, $c = 4186$ J/kg·K)
   
   ans: 195 J/K

B. 1. (2) A steam driven turbine typically spins the generators in an electric power plant. Why is it advantageous to have the temperature of the steam as high as possible?

2. (8) An ideal gas is taken through a Carnot cycle. The isothermal expansion occurs at 250°C and the isothermal compression takes place at 50°C. If the gas absorbs 1200 J of energy from the hot reservoir during the isothermal expansion, find: (a) the energy expelled to the cold reservoir in each cycle, and (b) the net work done by the gas in each cycle.
   
   ans: 741 J, 459 J
C. If 3200 J of heat flows from a heat reservoir at 500 K to another reservoir at 300 K through a conducting metal rod, find the change in entropy of (a) the hot reservoir, (b) the cold reservoir, (c) the metal rod, (d) the Universe.
   \[ \text{ans: } -6.40 \text{ J/K, 10.7 J/K, 0, 4.27 J/K} \]

D. 1. (3 pts) Is it possible to cool a room by leaving a refrigerator open? Explain.

2. (7) A 70 kg log falls from a height of 25 m into a lake. If the log, the lake and the air are all at 300 K, find the change in entropy of the Universe for this process.
   \[ \text{ans: 57.2 J/K} \]

E. One mole of an ideal monatomic gas is taken through the cycle shown. Heat is removed during BC to make the gas contract, added during CA to drive up the pressure, and added during AB to maintain the temperature as the gas expands against a piston. Calculate
   (a) the net work done by the gas,
   (b) If the heat energy expelled by the gas (during process BC) is 10.0 kJ, what is the efficiency of the cycle?
   \[ \text{ans: 4.05 kJ, 28.8\%} \]

F. A steam engine’s boiler is at 250°C, and the exhaust leaves at 110°C. It takes in 32 000 J from the boiler and expels 26 000 J to the cold reservoir in each cycle. (a) What is the efficiency of the engine? (b) How much work is done in each cycle? (c) What is the power output of the engine if each cycle lasts for 0.30 s? (d) What is the highest efficiency theoretically possible?
   \[ \text{ans: 0.1875, 6000 J, 20.0 kW, .268} \]