Review

<u>Chapter 4</u>: Magnetism

- All sections

<u>Chapter 5</u>: Electromagnetic Induction

- All sections

<u>Chapter 6</u>: Electromagnetic Oscillations and Alternating Current

- All sections

Chapter 4: Magnetism

Magnetic Field $\vec{B}$ A **magnetic field** $\vec{B}$ is defined in terms of the force $\vec{F}_B$ acting on a test particle with charge q moving through the field with velocity $\vec{v}$:

$$\vec{F}_B = q\vec{v} \times \vec{B}. \tag{28-2}$$

The SI unit for $\vec{B}$ is the **tesla** (T): $1\ \text{T} = 1\ \text{N/(A} \cdot \text{m)} = 10^4$ gauss.

Force Between Parallel Currents Parallel wires carrying currents in the same direction attract each other, whereas parallel wires carrying currents in opposite directions repel each other. The magnitude of the force on a length L of either wire is

$$F_{ba} = i_b L B_a \sin 90^\circ = \frac{\mu_0 L i_a i_b}{2\pi d}, \tag{29-13}$$

where d is the wire separation, and i_a and i_b are the currents in the wires.

Magnetic Force on a Current-Carrying Wire A straight wire carrying a current i in a uniform magnetic field experiences a sideways force

$$\vec{F}_B = i\vec{L} \times \vec{B}. \tag{28-26}$$

The force acting on a current element $i\,d\vec{L}$ in a magnetic field is

$$d\vec{F}_B = i\,d\vec{L} \times \vec{B}. \tag{28-28}$$

The direction of the length vector $\vec{L}$ or $d\vec{L}$ is that of the current i.

Torque on a Current-Carrying Coil A coil (of area A and N turns, carrying current i) in a uniform magnetic field $\vec{B}$ will experience a torque $\vec{\tau}$ given by

$$\vec{\tau} = \vec{\mu} \times \vec{B}. \tag{28-37}$$

Here $\vec{\mu}$ is the **magnetic dipole moment** of the coil, with magnitude $\mu = NiA$ and direction given by the right-hand rule.

A Charged Particle Circulating in a Magnetic Field A charged particle with mass m and charge magnitude $|q|$ moving with velocity $\vec{v}$ perpendicular to a uniform magnetic field $\vec{B}$ will travel in a circle. Applying Newton's second law to the circular motion yields

$$|q|vB = \frac{mv^2}{r}, \tag{28-15}$$

from which we find the radius r of the circle to be

$$r = \frac{mv}{|q|B}. \tag{28-16}$$

The frequency of revolution f, the angular frequency ω, and the period of the motion T are given by

$$f = \frac{\omega}{2\pi} = \frac{1}{T} = \frac{|q|B}{2\pi m}. \tag{28-19, 28-18, 28-17}$$

Question 1

An electron is accelerated from rest by a potential difference of 350 V. It then enters a uniform magnetic field of magnitude 200 mT with its velocity perpendicular to the field. Calculate (a) the speed of the electron and (b) the radius of its path in the magnetic field.

(a) Assume we have an electron accelerated using potential difference of $V = 350$ V, which gives the ion a speed of v, to find this speed we set the potential energy equals to the kinetic energy of the ion:

$$eV = \frac{1}{2}mv^2$$

$$v = \sqrt{\frac{2eV}{m}}$$

substitute with the givens to get:

$$\begin{aligned} v &= \sqrt{\frac{2(1.6 \times 10^{-19}\ \text{C})(350\ \text{V})}{9.11 \times 10^{-31}\ \text{kg}}} \\ &= 1.11 \times 10^{7}\ \text{m/s} \end{aligned}$$

$$\boxed{v = 1.11 \times 10^{7}\ \text{m/s}}$$

(b) Then the electron enters a region of uniform magnetic field, it moves in circular path with radius of:

$$r = \frac{mv}{eB}$$

substitute with givens to get:

$$\begin{aligned} r &= \frac{(9.11 \times 10^{-31} \text{ kg})(1.11 \times 10^{7} \text{ m/s})}{(1.6 \times 10^{-19} \text{ C})(200 \times 10^{-3} \text{ T})} \\ &= 3.16 \times 10^{-4} \text{ m} \end{aligned}$$

$$\boxed{r = 3.16 \times 10^{-4} \text{ m}}$$

The Biot–Savart Law The magnetic field set up by a current-carrying conductor can be found from the *Biot–Savart law.* This law asserts that the contribution $d\vec{B}$ to the field produced by a current-length element $i\,d\vec{s}$ at a point P located a distance r from the current element is

$$d\vec{B} = \frac{\mu_0}{4\pi}\frac{i\,d\vec{s} \times \hat{\mathrm{r}}}{r^2} \qquad \text{(Biot–Savart law).} \qquad (29\text{-}3)$$

Here $\hat{\mathrm{r}}$ is a unit vector that points from the element toward P. The quantity μ_0, called the permeability constant, has the value

$$4\pi \times 10^{-7}\ \mathrm{T \cdot m/A} \approx 1.26 \times 10^{-6}\ \mathrm{T \cdot m/A}.$$

Magnetic Field of a Long Straight Wire For a long straight wire carrying a current i, the Biot–Savart law gives, for the magnitude of the magnetic field at a perpendicular distance R from the wire,

$$B = \frac{\mu_0 i}{2\pi R} \qquad \text{(long straight wire).} \tag{29-4}$$

Magnetic Field of a Circular Arc The magnitude of the magnetic field at the center of a circular arc, of radius R and central angle ϕ (in radians), carrying current i, is

$$B = \frac{\mu_0 i \phi}{4\pi R} \qquad \text{(at center of circular arc).} \tag{29-9}$$

Question 3

The figure 1 shows a current loop consisting of two concentric circular arcs and two perpendicular radial lines. Determine the magnetic field at point P.

Hint: magnetic field of a circular arc of wire $B = \frac{\mu_0 I\theta}{4\pi r}$*, in which I is the current,* θ *is the angle of the arc, r is the radius of the arc and* μ_0 *is the permeability of free space.*

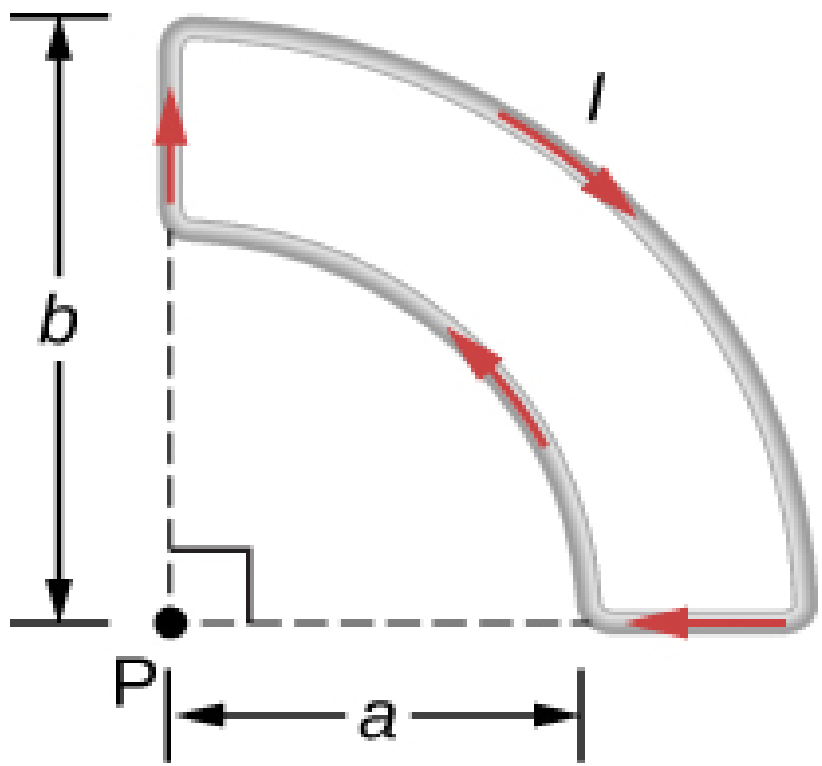


Figure 1

We can determine the magnetic field at point P using the Biot-Savart law. The radial and path length directions are always at a right angle, so the cross product turns into multiplication. The magnetic field due to the element $d\vec{l}$ of current-carrying wire is given by

$$d\overrightarrow{\mathbf{B}} = \frac{\mu_o}{4\pi}\frac{Id\overrightarrow{\mathbf{l}} \times \hat{\mathbf{r}}}{r^2} \tag{1}$$

This approximation is only good if the length of the line segment is very small compared to the distance from the current element to the point. If not, the integral form of the Biot-Savart law must be used over the entire line segment to calculate the magnetic field and as the radius of the circle is close to the length of the segments, therefore, we integrate over the radius. We also know that the distance along the path dl is related to the radius by $dl = 2\pi dR$

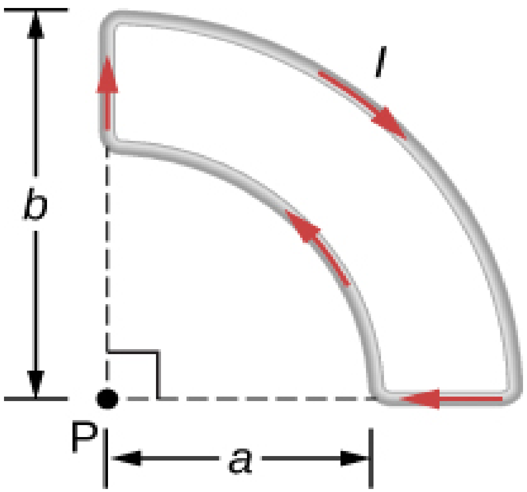
$$\begin{aligned} B &= \frac{\mu_o I}{4\pi R^2}\int_o^1 dl \\ &= \frac{\mu_o I}{4\pi R^2}(2\pi R) \\ &= \frac{\mu_o I}{2R} \end{aligned}$$

This is the magnetic field of the circle, so for a quarter, the magnetic field is given by

$$B_{arc} = \frac{\mu_o I}{2R} \times \frac{1}{4} = \frac{\mu_o I}{8R} \tag{2}$$

The current in the small arc is in the opposite direction of the current in the big arc, so the magnetic field due to both segments at point P is given by

$$\begin{aligned} B_{\text{net}} &= B_a - B_b \\ &= \frac{\mu_o I}{8a} - \frac{\mu_o I}{8b} \\ &= \boxed{\frac{\mu_o I}{8ab}(b-a)} \end{aligned}$$



Note that the two horizontal segments have no magnetic field at point P as they are parallel to P

Ampere's Law **Ampere's law** states that

$$\oint \vec{B} \cdot d\vec{s} = \mu_0 i_{\text{enc}} \qquad \text{(Ampere's law)}. \tag{29-14}$$

Fields of a Solenoid and a Toroid Inside a *long solenoid* carrying current i, at points not near its ends, the magnitude B of the magnetic field is

$$B = \mu_0 i n \qquad \text{(ideal solenoid)}, \tag{29-23}$$

where n is the number of turns per unit length. At a point inside a *toroid*, the magnitude B of the magnetic field is

$$B = \frac{\mu_0 i N}{2\pi} \frac{1}{r} \qquad \text{(toroid)}, \tag{29-24}$$

where r is the distance from the center of the toroid to the point.

Question 7

A solenoid is wound with 20 turns per centimeter. When the current is 5.2 A, what is the magnetic field within the solenoid?

In the solenoid near its center, the magnetic field is quite uniform and directly proportional to the current in the wire where the magnetic field along the central axis of an infinite solenoid is given by equation 12.30 in the form

$$B = \mu_o n I \tag{1}$$

Where n is the number of turns per unit length and μ_o is the free space permeability and equals $4\pi \times 10^{-7}\ \mathrm{T \cdot m/A}$.

Now let us plug the values for μ_o, I and n into equation (1) to get the magnetic field in the solenoid

$$\begin{aligned}
B &= \mu_o n I \\
&= \left(4\pi \times 10^{-7}\ \mathrm{T \cdot m/A}\right)(2000\ \ \mathrm{turns/m}\ )(5.2\ \mathrm{A}) \\
&= \boxed{1.3 \times 10^{-2}\ \mathrm{T}}
\end{aligned}$$

You can find the direction of the magnetic field with a right-hand rule. Curl your fingers in the direction of the current, and your thumb points along the magnetic field in the interior of the solenoid.

Chapter 5: Electromagnetic Induction

Magnetic Flux The *magnetic flux* Φ_B through an area A in a magnetic field $\vec{B}$ is defined as

$$\Phi_B = \int \vec{B} \cdot d\vec{A}, \qquad (30\text{-}1)$$

where the integral is taken over the area. The SI unit of magnetic flux is the weber, where $1\ \text{Wb} = 1\ \text{T} \cdot \text{m}^2$. If $\vec{B}$ is perpendicular to the area and uniform over it, Eq. 30-1 becomes

$$\Phi_B = BA \qquad (\vec{B} \perp A, \vec{B} \text{ uniform}). \qquad (30\text{-}2)$$

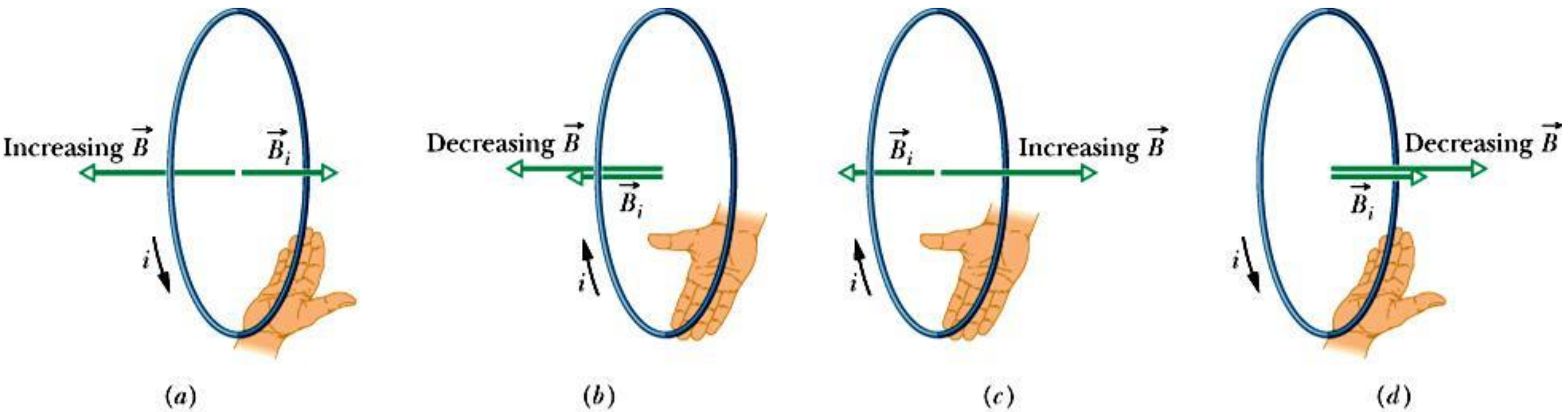
Faraday's Law of Induction If the magnetic flux Φ_B through an area bounded by a closed conducting loop changes with time, a current and an emf are produced in the loop; this process is called *induction*. The induced emf is

$$\mathscr{E} = -\frac{d\Phi_B}{dt} \qquad \text{(Faraday's law).} \qquad (30\text{-}4)$$

If the loop is replaced by a closely packed coil of N turns, the induced emf is

$$\mathscr{E} = -N\frac{d\Phi_B}{dt}. \qquad (30\text{-}5)$$

Lenz's Law An induced current has a direction such that the magnetic field *due to the current* opposes the change in the magnetic flux that induces the current. The induced emf has the same direction as the induced current.



The direction of the current *i* induced in a loop is such that the current's magnetic field B_{ind} opposes the change in the magnetic field inducing *i*. The field is always directed opposite an increasing field (a, c) and in the same direction (b, d) as a decreasing field *B*.

The curled–straight right-hand rule gives the direction of the induced current based on the direction of the induced field.

Question 4

A single-turn circular loop of wire of radius 50 mm lies in a plane perpendicular to a spatially uniform magnetic field. During a 0.10-s time interval, the magnitude of the field increases uniformly from 200 to 300 mT.

(a) Determine the emf induced in the loop.

(b) If the magnetic field is directed out of the page, what is the direction of the current induced in the loop?

(a) We want to determine the induced emf. The magnetic field is perpendicular to the plane of the loop and constant over each spot in the loop, the dot product of the magnetic field and normal to the area unit vector turns into multiplication and the magnetic flux is given by equation

$$\Phi_m = BA \tag{1}$$

The magnetic field changes from 0.20 T to 0.30 T, so it is variable and the remaining parameters are constant and equation (1) will be in the form ($\Delta\Phi_m = A\Delta B$). So, we can use this expression of $\Delta\Phi_m$
to get the magnitude of the induced emf as next

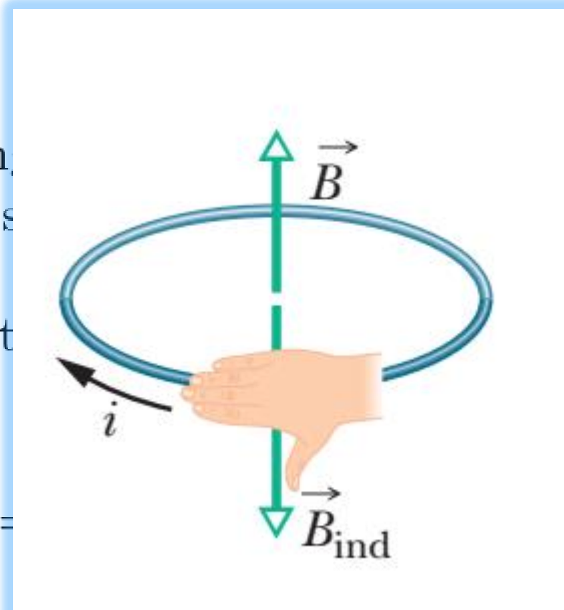
$$\varepsilon = \left|\frac{-N\Delta\Phi_m}{t}\right| = \left|\frac{-NA\Delta B}{t}\right| \tag{2}$$

Now let us plug our values for N,$\Delta B, A$ and t into equation (2) to get ε where $\Delta B = 0.30\,\mathrm{T} - 0.20\,\mathrm{T}$ and the area is $\pi r^2 = \pi(0.05\,\mathrm{m})^2$

$$\varepsilon = \left|\frac{-NA\Delta B}{t}\right| = \left|\frac{-(1)(0.1\ \mathrm{T})(0.00785\ \mathrm{m}^2)}{0.10\,\mathrm{s}}\right| = \boxed{7.8\ \mathrm{mV}}$$

(a) We want to determine the induced emf. The magnetic field is perpendicular to the plane of the loop and constant over each spot in the loop, the dot product of the magnetic field and normal to the area unit vector turns into multiplication and the magnetic flux is given by equation

$$(1)$$



The magnetic field chan T, so it is variable and the remaining parameters (1) will be in the form ($\Delta\Phi_m = A\Delta B$). So, we $\Delta\Phi_m$ to get the magnitude of t

$$\varepsilon = \qquad (2)$$

Now let us plug our values for N,ΔB, A and t into equation (2) to get ε where $\Delta B = 0.30\,\mathrm{T} - 0.20\,\mathrm{T}$ and the area is $\pi r^2 = \pi(0.05\,\mathrm{m})^2$

$$\varepsilon = \left|\frac{-NA\Delta B}{t}\right| = \left|\frac{-(1)(0.1\ \mathrm{T})(0.00785\ \mathrm{m}^2)}{0.10\,\mathrm{s}}\right| = \boxed{7.8\ \mathrm{mV}}$$

Question 8

The rod shown on figure 2 moves to the right on essentially zero-resistance rails at a speed of v = 3.0m/s. If B = 0.75T everywhere in the region, what is the current through the 5.0-Ω resistor? Does the current circulate clockwise or counterclockwise?

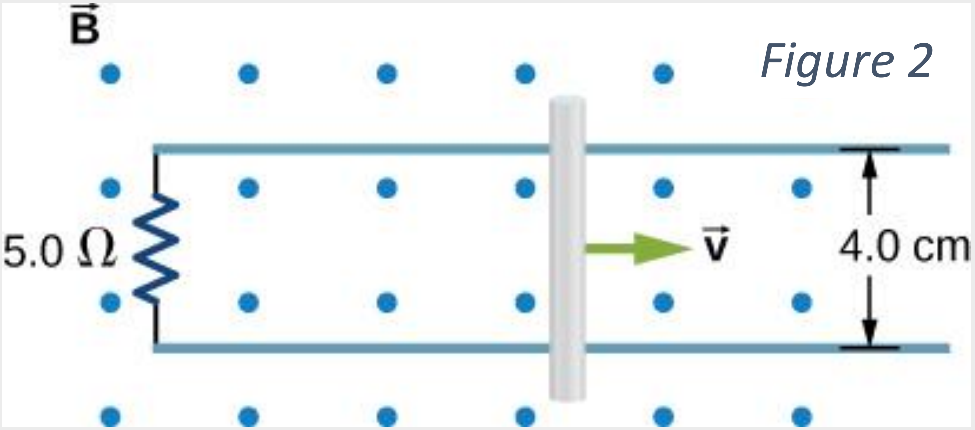


Figure 2

The induced emf magnitude:

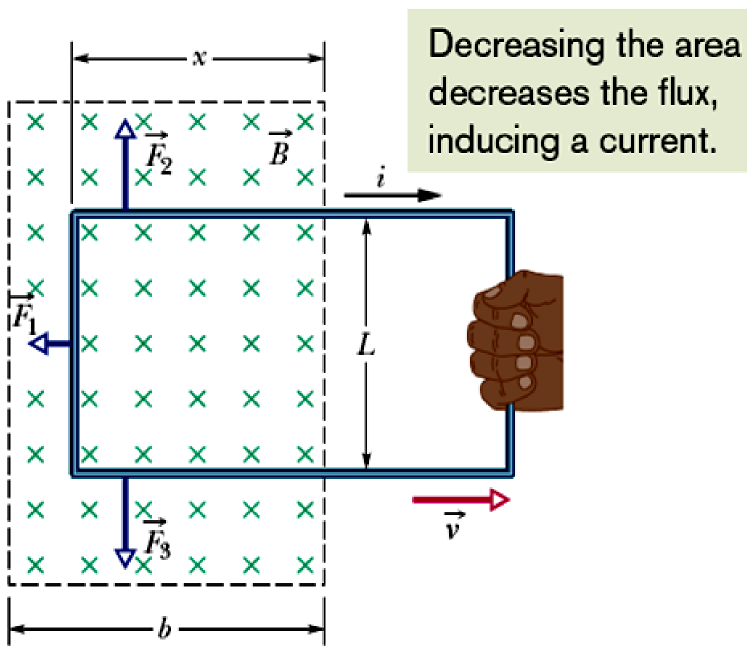
$$\varepsilon = \frac{d\Phi_B}{dt} = \frac{d}{dt}BLx = BL\frac{dx}{dt} = BLv$$

The induced current:

$$i = \frac{BLv}{R}$$

The net deflecting force:

$$F = F_1 = iLB\sin 90^0 = iLB = \frac{B^2L^2v}{R}$$



We want to determine the current through the resistor and the direction of the current. The strategy is to find the induced emf using Faraday's law in the rod then use Ohm's law to get the current flows in the circuit. Due to the motion of the rod, we can restate Faraday's law to get the magnitude of the emf ε in terms of the moving of rod using equation 13.5 in the form

$$\varepsilon = Blv \tag{1}$$

Where in this case the magnetic flux changes due to the motion of the rod. Now we can plug our value for B, l and v into equation (1) to get the induced emf due to the motion of the rod

$$\varepsilon = Blv = (0.75\ \mathrm{T})(0.04\ \mathrm{m})(3.0\ \mathrm{m/s}) = 0.09\ \mathrm{V}$$

The current flows in the closed area and the resistor is given by Ohm's law

$$I = \frac{\varepsilon}{R} = \frac{0.09\ \mathrm{V}}{5.0\ \Omega} = \boxed{18\,\mathrm{mA}}$$

The rod moves to the right, where the enclosed area increases, so the magnetic flux in the enclosed area increases. So, the rod induces a magnetic field in the opposite direction of the applied magnetic field. By using RHR 2 when your thumb is to left, we could obtain that the current flow in the circuit is **clockwise** and flows in the resistor from the bottom to the top.

Inductors An **inductor** is a device that can be used to produce a known magnetic field in a specified region. If a current i is established through each of the N windings of an inductor, a magnetic flux Φ_B links those windings. The **inductance** L of the inductor is

$$L = \frac{N\Phi_B}{i} \qquad \text{(inductance defined).} \tag{30-28}$$

The SI unit of inductance is the **henry** (H), where 1 henry = 1 H = 1 $\text{T}\cdot\text{m}^2/\text{A}$. The inductance per unit length near the middle of a long solenoid of cross-sectional area A and n turns per unit length is

$$\frac{L}{l} = \mu_0 n^2 A \qquad \text{(solenoid).} \tag{30-31}$$

Self-Induction If a current i in a coil changes with time, an emf is induced in the coil. This self-induced emf is

$$\mathscr{E}_L = -L\frac{di}{dt}. \tag{30-35}$$

The direction of $\mathscr{E}_L$ is found from Lenz's law: The self-induced emf acts to oppose the change that produces it.

Series *RL* Circuits If a constant emf $\mathscr{E}$ is introduced into a single-loop circuit containing a resistance R and an inductance L, the current rises to an equilibrium value of $\mathscr{E}/R$ according to

$$i = \frac{\mathscr{E}}{R}(1 - e^{-t/\tau_L}) \qquad \text{(rise of current).} \qquad (30\text{-}41)$$

Here τ_L $(= L/R)$ governs the rate of rise of the current and is called the **inductive time constant** of the circuit. When the source of constant emf is removed, the current decays from a value i_0 according to

$$i = i_0 e^{-t/\tau_L} \qquad \text{(decay of current).} \qquad (30\text{-}45)$$

Magnetic Energy If an inductor L carries a current i, the inductor's magnetic field stores an energy given by

$$U_B = \tfrac{1}{2}Li^2 \qquad \text{(magnetic energy).} \qquad (30\text{-}49)$$

If B is the magnitude of a magnetic field at any point (in an inductor or anywhere else), the density of stored magnetic energy at that point is

$$u_B = \frac{B^2}{2\mu_0} \qquad \text{(magnetic energy density).} \qquad (30\text{-}55)$$

LC Energy Transfers In an oscillating LC circuit, energy is shuttled periodically between the electric field of the capacitor and the magnetic field of the inductor; instantaneous values of the two forms of energy are

$$U_E = \frac{q^2}{2C} \quad \text{and} \quad U_B = \frac{Li^2}{2}, \tag{31-1, 31-2}$$

where q is the instantaneous charge on the capacitor and i is the instantaneous current through the inductor. The total energy $U\ (= U_E + U_B)$ remains constant.

***LC* Charge and Current Oscillations** The principle of conservation of energy leads to

$$L \frac{d^2q}{dt^2} + \frac{1}{C} q = 0 \qquad (LC \text{ oscillations}) \tag{31-11}$$

as the differential equation of LC oscillations (with no resistance). The solution of Eq. 31-11 is

$$q = Q \cos(\omega t + \phi) \qquad \text{(charge)}, \tag{31-12}$$

in which Q is the *charge amplitude* (maximum charge on the capacitor) and the angular frequency ω of the oscillations is

$$\omega = \frac{1}{\sqrt{LC}}. \tag{31-4}$$

The phase constant ϕ in Eq. 31-12 is determined by the initial conditions (at $t = 0$) of the system.

The current i in the system at any time t is

$$i = -\omega Q \sin(\omega t + \phi) \qquad \text{(current)}, \tag{31-13}$$

in which ωQ is the *current amplitude* I.

Question 9

The self-inductance and capacitance of an oscillating *LC* circuit are $L=20mH$ and $C=1.0\mu F$, respectively. (a) What is the frequency of the oscillations? (b) If the maximum potential difference between the plates of the capacitor is 50 V, what is the maximum current in the circuit?

First, we use the equation for angular frequency in LC circuits to calculate ω. Then, we proceed to calculate the frequency of oscillation of the circuit (f).

$$\begin{aligned}
\omega &= \sqrt{\frac{1}{LC}} \\
&= \sqrt{\frac{1}{(20 \cdot 10^{-3})\,(1.0 \cdot 10^{-6})}} \\
&= 7.07 \cdot 10^{3}\ \frac{\mathrm{rad}}{\mathrm{s}} \\
f &= \frac{\omega}{2\pi} \\
&= \frac{7.07 \cdot 10^{3}}{2\pi} \\
&= \boxed{1125\ \mathrm{Hz}}
\end{aligned}$$

We continue to obtain an expression for the maximum voltage (ε_0) by differentiating the equation for the current oscillations in LC circuits. Then, we solve for the initial charge on the capacitor (q_0) in the resulting equation.

$$\begin{aligned}
I(t) &= -\omega q_0 \sin(\omega t + \phi) \\
\implies \frac{dI}{dt} &= -\omega^2 q_0 \cos(\omega t + \phi) \\
\varepsilon(t) &= -L\frac{dI}{dt} \\
&= \omega^2 L q_0 \cos(\omega t + \phi) \\
\implies \varepsilon_0 &= \omega^2 L\, q_0 \\
\implies q_0 &= \frac{\varepsilon_0}{\omega^2 L} \\
&= \frac{50}{(7.07 \cdot 10^3)^2 (20 \cdot 10^{-3})} \\
&= 5.0 \cdot 10^{-5}\ \mathrm{C}
\end{aligned}$$

Once we have obtained q_0, we proceed to calculate the maximum value of the current.

$$\begin{aligned}
I_0 &= \omega q_0 \\
&= \left(7.07 \cdot 10^3\right)\left(5.0 \cdot 10^{-5}\right) \\
&= \boxed{0.35\ \mathrm{A}}
\end{aligned}$$

Alternating Currents; Forced Oscillations A series *RLC* circuit may be set into *forced oscillation* at a *driving angular frequency* ω_d by an external alternating emf

$$\mathscr{E} = \mathscr{E}_m \sin \omega_d t. \tag{31-28}$$

The current driven in the circuit is

$$i = I \sin(\omega_d t - \phi), \tag{31-29}$$

where ϕ is the phase constant of the current.

Resonance The current amplitude I in a series *RLC* circuit driven by a sinusoidal external emf is a maximum ($I = \mathscr{E}_m/R$) when the driving angular frequency ω_d equals the natural angular frequency ω of the circuit (that is, at *resonance*). Then $X_C = X_L$, $\phi = 0$, and the current is in phase with the emf.

Single Circuit Elements The alternating potential difference across a resistor has amplitude $V_R = IR$; the current is in phase with the potential difference.

For a *capacitor*, $V_C = IX_C$, in which $X_C = 1/\omega_d C$ is the **capacitive reactance;** the current here leads the potential difference by 90° ($\phi = -90° = -\pi/2$ rad).

For an *inductor*, $V_L = IX_L$, in which $X_L = \omega_d L$ is the **inductive reactance;** the current here lags the potential difference by 90° ($\phi = +90° = +\pi/2$ rad).

Series *RLC* Circuits For a series RLC circuit with an alternating external emf given by Eq. 31-28 and a resulting alternating current given by Eq. 31-29,

$$I = \frac{\mathscr{E}_m}{\sqrt{R^2 + (X_L - X_C)^2}}$$

$$= \frac{\mathscr{E}_m}{\sqrt{R^2 + (\omega_d L - 1/\omega_d C)^2}}$$

(current amplitude) (31-60, 31-63)

and $$\tan \phi = \frac{X_L - X_C}{R} \quad \text{(phase constant).} \qquad (31\text{-}65)$$

Defining the impedance Z of the circuit as

$$Z = \sqrt{R^2 + (X_L - X_C)^2} \quad \text{(impedance)} \qquad (31\text{-}61)$$

allows us to write Eq. 31-60 as $I = \mathscr{E}_m/Z$.

Question 5

(a) What is the resonant frequency of an *RLC* series circuit with R=20Ω, L=2.0H, and C=4.0μF ?

(b) What is the impedance of the circuit at resonance?

Part A

Identify the unknown:

The resonant frequency

List the Knowns:

Resistance: $R = 20\ \Omega$

Capacitance: $C = 4\ \mu\text{F} = 4 \times 10^{-6}$ F

Self-inductance: $L = 2\ \text{mH} = 2 \times 10^{-3}$ H

Set Up the Problem:

The resonant frequency for a RLC circuit:

$$f_0 = \frac{1}{2\pi}\sqrt{\frac{1}{LC}}$$

Solve the Problem:

$$f_0 = \frac{1}{2\pi}\sqrt{\frac{1}{2 \times 10^{-3} \times 4 \times 10^{-6}}} = \boxed{1779\ \text{Hz}}$$

Part B

Identify the unknown:

The impedance of the circuit at resonance

Set Up the Problem:

Impedance of an ac circuit (RLC):

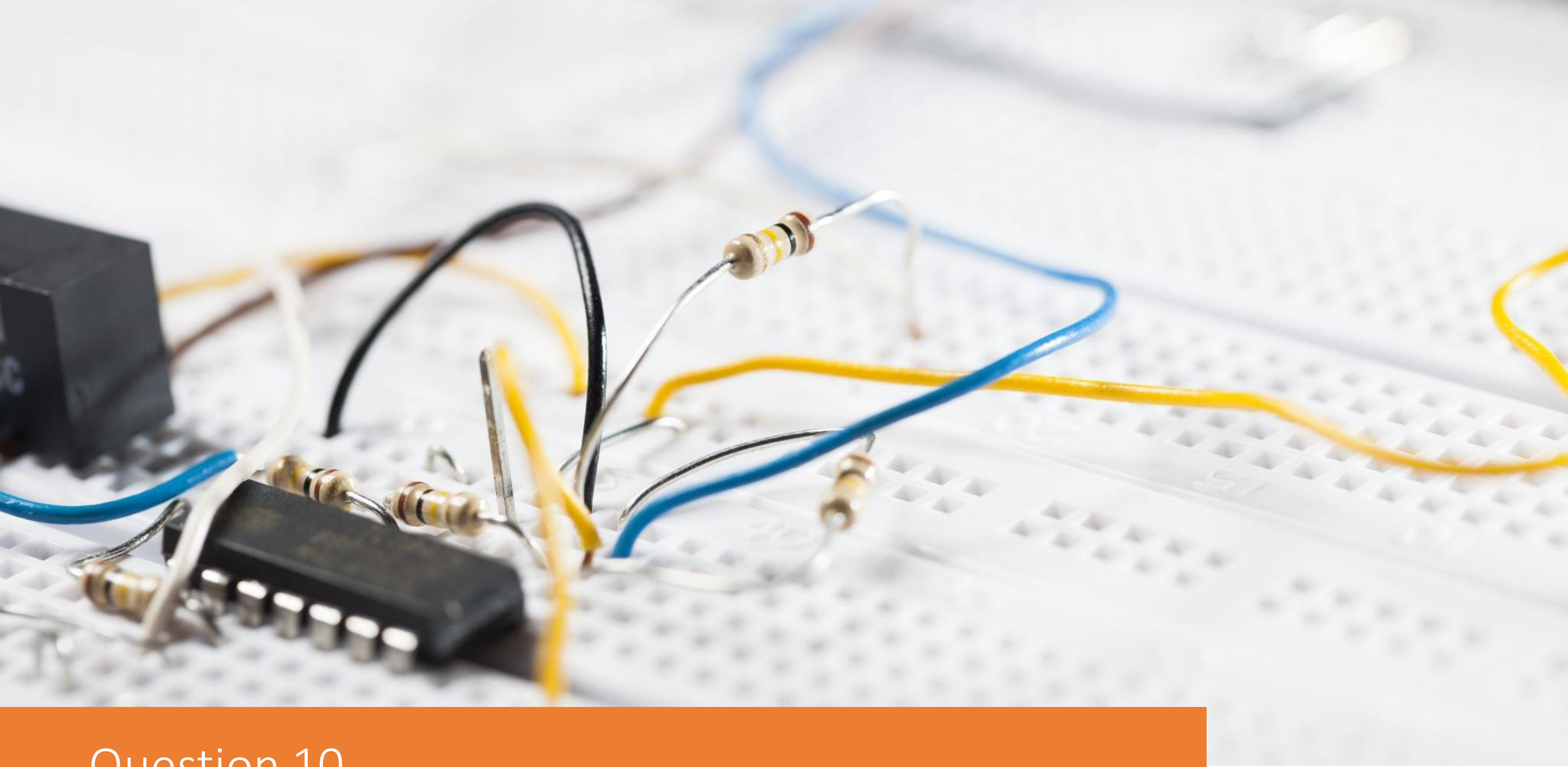
$$Z = \sqrt{R^2 + (X_L - X_C)^2}$$

At the resonant frequency,
$(X_L = X_C)$, so:

$$Z = R$$

Solve the Problem:

$$Z = \boxed{20\ \Omega}$$



Question 10

An *RLC* series circuit with $R=600\Omega$, $L=30mH$, and $C=0.050\mu F$ is driven by an ac source whose frequency and voltage amplitude are 500 Hz and 50 V, respectively. (a) What is the impedance of the circuit? (b) What is the amplitude of the current in the circuit? (c) What is the phase angle between the emf of the source and the current

Part A

Identify the unknown:

The impedance

List the Knowns:

Peak voltage: $V_0 = 50$ V

Angular frequency: $\omega = 2\pi f = 2\pi \times 500 =$ 1000π rad/s

Resistance: $R = 600\ \Omega$

Capacitance: $C = 0.05\ \mu\text{F} = 0.05 \times 10^{-6}$ F

Self-inductance: $L = 30$ mH $= 30 \times 10^{-3}$ H

Set Up the Problem:

Inductive reactance:

$$X_L = \omega L = 1000\pi \times 30 \times 10^{-3} = 94\ \Omega$$

Capacitive reactance:

$$X_C = \frac{1}{\omega C} = \frac{1}{1000\pi \times 0.05 \times 10^{-6}} = 6366\ \Omega$$

Impedance of an ac circuit (RLC):

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

Solve the Problem:

$$Z = \sqrt{(600)^2 + (94 - 6366)^2} = \boxed{6300\ \Omega}$$

Part B

Identify the unknown:

The current

Set Up the Problem:

The peak current:

$$I_0 = \frac{V_0}{Z}$$

Solve the Problem:

$$I_0 = \frac{50}{6300} = \boxed{7.94 \times 10^{-3}\ \mathrm{A}}$$

Part C

Identify the unknown:

Phase angle between the emf of the source and the current.

Set Up the Problem:

Phase angle of the ac circuit:

$$\Phi = \tan^{-1} \frac{X_L - X_C}{R}$$

Solve the Problem:

$$\Phi = \tan^{-1}\left(\frac{94 - 6366}{600}\right) = \boxed{-84.53^\circ} = \boxed{-1.47542\ \mathrm{rad}}$$