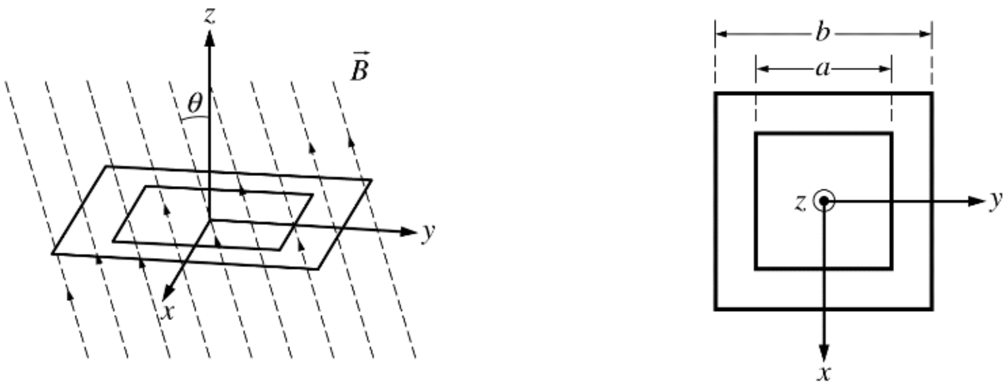
AP Physics C: Electricity & Magnetism
Unit 6 Practice Exercises

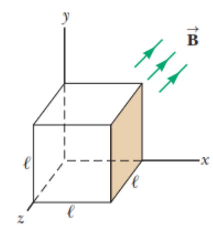
Magnetic Flux

1. Two square loops of thin metal wire are position on the horizontal xy-plane in a magnetic field B that is directed upward through the loops at an angle θ with the vertical z-axis as shown below. The small loop has side length a. The large loop has side length b. Determine the magnetic flux between the loops.



Top View

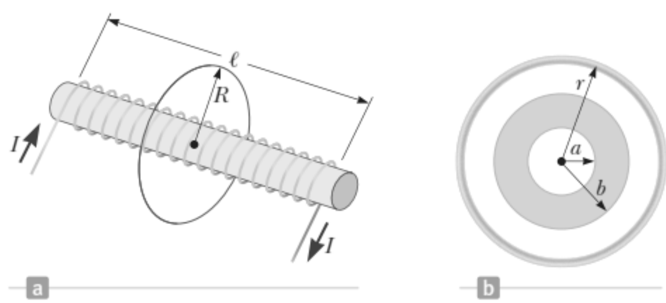
2. A cube of edge length 2.50 cm is positioned as shown. A uniform magnetic field given by $B = 5\hat{\imath} + 4\hat{\jmath} + 3\hat{k})$T exists throughout the region.



a) Calculate the magnetic flux through the shaded face.

b) What is the total flux through the six faces?

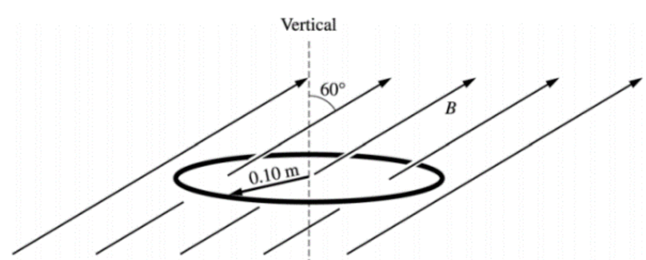
3. A solenoid of radius *r* = 1.25 cm and length 30.0 cm has 300 turns and carries 12.0 A.



a) Calculate the flux through the surface of a disk-shaped area of radius *R* - 5.00 cm that is positioned perpendicular to and centered on the axis of the solenoid as shown.

b) Calculate the flux through the shaded area, which is an annulus with an inner radius of *a* = 0.400 cm and an outer radius of *b* = 0.800 cm.

4. A circular wire loop with radius 0.10 m and resistance 50 Ω is suspended horizontally in a magnetic field of magnitude B directed upward at angle of 60° with the vertical, as shown. The magnitude of the field is given as a function of time by the equation

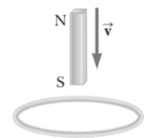


$B = 4(1 - 0.2t)$. Determine the magnetic flux through the loop as a function of time.

11.2 – Faraday's Law

1. An airplane with a wing span of 30.0 m flies parallel to the Earth's surface at a location where the downward component of the Earth's magnetic field is 0.60 x10^{-4} T. Find the difference in potential between the wing tips is the speed of the plane is 250 m/s.

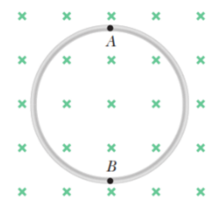
2. A bar magnet is held in a vertical orientation above a loop of wire that lies in the horizontal plane as shown. The south end of the magnet is toward the loop. After the magnet is dropped, what is true of the induced current in the loop a) before and b) after the magnet passes through the loop?



3. A flat loop of wire consisting of a single turn of cross-sectional area 8.00 cm^2 is perpendicular to a magnetic field that increases uniformly in magnitude from 0.500 T to 2.50 T in 1.00 s. What is the resulting induced current if the loop has a resistance of 2.00 O?

4. A 25-turn circular coil of wire has diameter 1.00 m. It is placed with its axis along the direction of the Earth's magnetic field of 50.0 mT and then in 0.200 s is flipped 180°. An average emf of what magnitude is generated in the coil?

5. The flexible loop in shown has a radius of 12.0 cm and is in a magnetic field of magnitude 0.150 T. The loop is grasped at points *A* and *B* and stretched until its area is nearly zero. If it takes 0.200 s to close the loop, what is the magnitude of the average induced emf in it during this time interval?

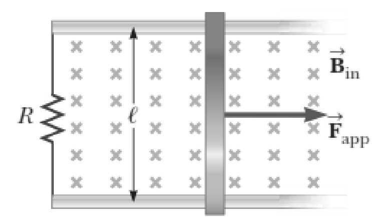


6. A magnetic field has a strength given by $B(t) = 6t^2 - 20t$ and acts out of the plane of this page. A circular loop of wire within the plane of this page has the field pass through it.

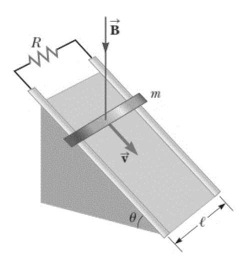
a) Find the induced emf in this wire as a function of time.
b) Find the direction of the current in the wire at t = 3.0 s.

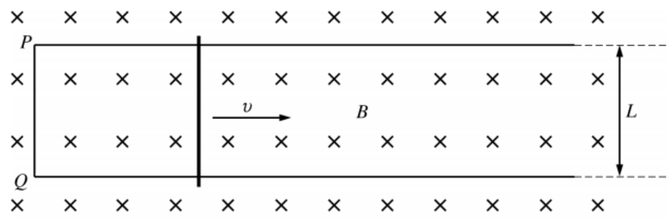
7. A long solenoid has n = 400 turns per meter and carries a current given by $I(t) = 30.0(1 - e^{-1.60t})$. Inside the solenoid and coaxial with it is a coil that has a radius of R = 6.00 cm and consists of N = 250 turns of fine wire. What is the emf induced in the coil by the changing coil?

8. Consider the arrangement shown. Assume that R = 6.00 Ω, l=1.20 m, and a uniform 2.50-T magnetic field is directed into the page. At what speed should the bar be moved to produce a current of 0.500 A in the resistor?



9. The figure on the right shows a bar of mass *m* that can slide without friction on a pair of rails separated by a distance l, and located on an inclined plane that makes an angle θ with respect to the ground. The resistance of the resistor is *R*, and a uniform magnetic field of magnitude *B* is directed downward, perpendicular to the ground, over the entire region through which the bar moves. With what constant speed *v* does the bar slide along the rails?





Top View

10. In the diagram above, a nichrome wire of resistance per unit length λ is bent at points P and Q to form horizontal conducting rails that are a distance L apart. The wire is placed within a uniform magnetic field of magnitude B point into the page. A conducting rod of negligible resistance, which was aligned with end PQ at time t = 0, slides to the right with constant speed v and negligible friction.

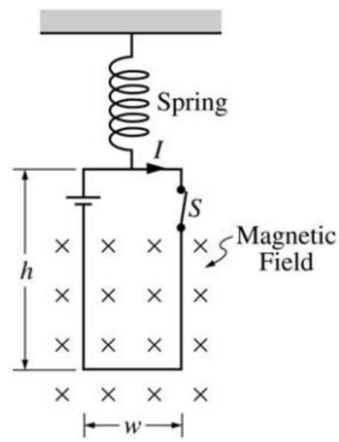
a) Indicate the direction of the current induced in the circuit.

b) Derive an expression for the magnitude of the induced currents a function of time t.

c) Derive an expression for the magnitude force on the rod as a function of time.

d) The force pulling the rod is now removed. What will happen to the speed of the rod?

11. A loop of wire of width w and height h contains a switch and a battery and is connected to a spring of elastic constant k, as shown. The loop carries a current I in a clockwise direction, and its bottom is in a constant, uniform magnetic field directed into the plane of the page.

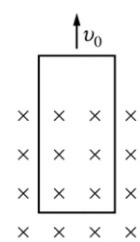


a) What is direction of the magnetic force that acts on the sides of the loop.

b) The switch S is opened, and the loop eventually comes to rest at a new equilibrium position that is a distance x from its former position. Derive an expression for the magnitude, B_0, of the uniform magnetic field.

c) The spring and loop are replaced with a loop of the same direction and resistance R but without the battery and switch. The new loop is pulled upward, out of the magnetic field, at constant speed v_0.

i. The new loop is shown below, indicate the direction of the induced current in the loop as the loop moves upward.



ii. Derive an expression for the magnitude of this current.

d) Derive an expression for the power dissipated in the loop as the loop is pulled at constant speed out of the field.

<u>11.4 – Inductance</u>

1. A 2.00-H inductor carries a steady current of 0.500 A. When the switch in the circuit is opened, the current effectively drops to zero after a time of 10.0 ms. What is the average induced emf in the inductor during this time interval?

2. An emf of 24.0 mV is induced in a 500-turn coil when the current is changing at the rate of 10.0 A/s. What is the magnetic flux through each turn of the coil at an instant when the current is 4.00 A?

3. The current in a 90.0-mH inductor changes with time as $i(t) = 1.00t^2 - 6.00t$, where i is in amperes and t is in seconds.

a) Find the magnitude of the induced emf at t = 1.00 s.

b) At what time is the emf zero?

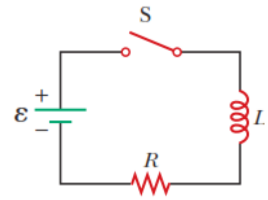
4. A 12.0-V battery is connected into a series circuit containing a 10.0-V resistor and a 2.00-H inductor.

a) In what time interval will the current reach 50.0% of its final value?

$$I(t) = \frac{V}{R}\left(1 - e^{-\frac{R}{L}t}\right) \rightarrow 0.6 = 1.2(1 - e^{-5t})$$

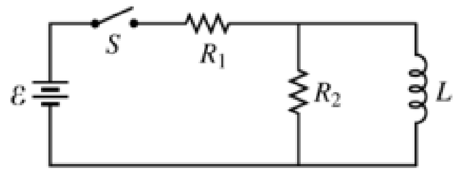
b) In what time interval will the current reach 95.0% of its final value?

5. Consider the circuit shown.



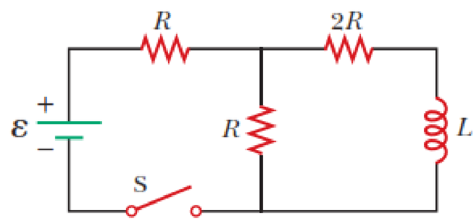
a) When the switch is in position *a*, for what value of *R* will the circuit have a time constant of 15.0 μs?
b) What is the current in the inductor at the instant the switch is thrown to position *b*?

6. In the circuit shown, resistors 1 and 2 with resistances shown and an inductor of inductance L are connected to a battery of emf ε and a switch S. The switch is closed at time t = 0.



a) Determine the current through resistor 1 immediately after the switch is closed.
b) Determine the magnitude of the initial rate of change of current, dI/dt in the inductor.
c) Determine the current through the battery a long time after the switch has been closed.
d) Sketch a graph of the current through the battery as a function of time.
e) Some time after steady state is reached, the switch is opened. Determine the voltage across resistor 2 just after the switch has been opened.

7. The switch in the circuit shown is open for *t*<0 and is then closed at time *t*=0. Assume $R = 4.00\ \Omega$, $L = 1.00$ H, and $\varepsilon = 10.0$ V.



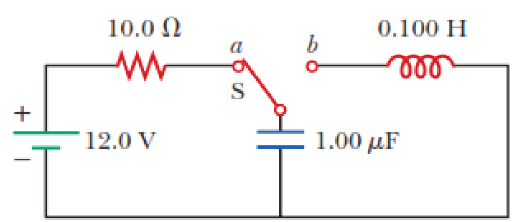
a) Find the current in the inductor.
c) Find the current in the switch as functions of time.

8. An air-core solenoid with 68 turns is 8.00 cm long and has a diameter of 1.20 cm. When the solenoid carries a current of 0.770 A, how much energy is stored in its magnetic field?

9. An emf of 96.0 mV is induced in the windings of 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?

10. A 1.00-μF capacitor is charged by a 40.0-V power supply. The fully charged capacitor is then discharged through a 10.0-mH inductor. Find the maximum current in the resulting oscillations.

11. The switch in Figure P32.53 is connected to position *a* for a long time interval. At *t*=0, the switch is thrown to position *b*. After this time, what are



a) the frequency of oscillation of the *LC* circuit
b) the maximum charge that appears on the capacitor
c) the maximum current in the inductor
d) the total energy the circuit possesses at *t*=3.00 s?