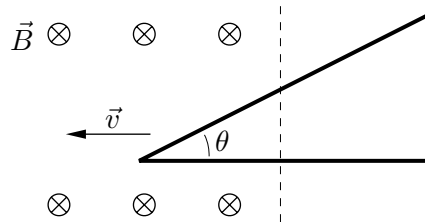


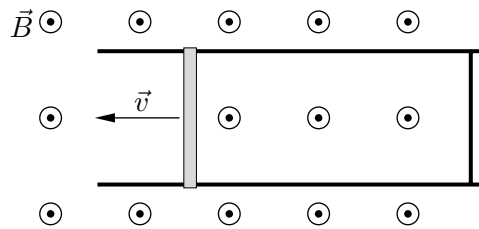
Problem Set 7
(due Friday, October 12)

1. You have a loop of wire and a bar magnet. List at least three different ways to change the magnetic flux through your loop (and hence to induce a current in it). For each way of changing the flux, explain whether the force that causes the electrons to flow around the wire is an electric force or a magnetic force.
2. The figure below shows a triangular loop of wire that is being pushed with speed $|\vec{v}|$ into a magnetic field. Left of the dashed line, there is a uniform field \vec{B} pointing into the page; right of the dashed line there is no magnetic field. The left end of the triangle enters the field at time $t = 0$. Use the magnetic force law (*not* the flux rule or Faraday's law) to compute the electromotive force in the loop. (Remember that electromotive force is the work per unit charge done on each moving electron, not counting any possible resistive forces in the wire. You can compute the work as $\vec{F}_B \cdot \vec{ds}$, where \vec{ds} is the displacement along the wire.) Please express your answer in terms of \vec{v} , t , \vec{B} , and θ . What is the direction of the induced current?



3. Consider again the situation described in the previous problem. This time, use the "flux rule" (or Faraday's law, as your textbook calls it) to compute the electromotive force. According to Lenz's law, what is the direction of the induced current?
4. A single, circular loop of wire has a radius of 12 cm and a resistance of 8.5Ω . A magnetic field in this region, pointing perpendicular to the loop, is initially zero, then increases linearly with time until after 2 seconds it has strength 0.5 T, then remains constant for 2 seconds, then decreases linearly to zero in the following 2 seconds. Calculate the emf in the loop during each of these three time intervals. Is the induced current caused by an electric force or a magnetic force?
5. A $20 \text{ m}\Omega$ square loop of wire, 20 cm on a side, has its plane perpendicular to a uniform magnetic field of 2.0 T. If you pull two opposite sides of the loop away from each other, the other two sides automatically draw toward each other, reducing the area of the enclosed loop. If the area is reduced to zero in $1/5$ second, what are (a) the average emf and (b) the average current induced in the loop during this brief time interval? Is the induced current caused by an electric force or a magnetic force?

6. A long solenoid with a radius of 25 mm has 100 turns/cm. A single loop of wire of radius 5.0 cm is placed around the solenoid, with central axes of the loop and solenoid coinciding. In 10 ms the current in the solenoid is reduced from 1.0 A to 0.5 A at a uniform rate. What emf appears in the loop? (Hint: You'll need to recall or look up the formula for the magnetic field inside a solenoid.)
7. An electric generator consists of 100 turns of wire formed into a rectangular loop 50 cm by 30 cm, placed entirely in a uniform magnetic field with magnitude 3.5 T. The loop is spun at 1000 revolutions per minute about an axis perpendicular to \vec{B} . Calculate the induced emf as a function of time. (Hint: first find a formula for the magnetic flux as a function of time, then take the derivative.)
8. The figure below shows two horizontal metal rails, connected with a strip of metal at the far right. The rails are 25 cm apart, and the region is filled with a uniform magnetic field of 0.35 T pointing out of the page. A metal rod, touching both rails, is pushed so that it slides along them leftward at 55 cm/s. (a) What is the emf generated in the sliding rod? (b) If the rod has a resistance of 18Ω and the rails and connecting strip have negligible resistance, how much current flows through the rod? (c) At what rate is mechanical energy (from whoever is pushing) being converted to thermal energy in this system?



9. Electric generators on airplanes run at higher frequency (I think about 500 Hz) than ordinary (60 Hz) terrestrial generators. Why do you suppose this is?
10. The current in a circuit containing a coil, resistor, and battery has reached a constant value. Does the coil have an inductance? Does the coil affect the value of the current?
11. A coiled telephone cord has 70 turns, a cross-sectional diameter of 1.3 cm, and an unstretched length of 60 cm. Estimate the self-inductance of this cord.
12. The inductance of a close-packed coil of 400 turns is 8.0 mH. Calculate the magnetic flux through the coil when the current is 5.0 mA.

Study Guide for Quiz 7

An induced electromotive force (emf) is an “effective voltage” created by an electric or magnetic force acting on the electrons (or other charge carriers) in a circuit. More precisely, it is the work per unit charge done by the outside force on the charge carriers.

Motional emf is caused by the motion of a wire through a magnetic field. In this case the force on the electrons is a magnetic force, and can be calculated from the magnetic force law ($q\vec{v} \times \vec{B}$). For a loop of wire, however, it is often more convenient to use the “flux rule”:

$$(\text{induced emf}) = -\frac{d}{dt}(\text{magnetic flux through loop}).$$

The other way to induce an emf is to put a loop in a *changing* magnetic field. The formula for the induced emf is again given by the preceding equation, which in this case is called Faraday’s law. Note, however, that if the loop of wire is not moving, the force on the electrons cannot be a magnetic force ($\vec{v} = 0$). Instead it is an electric force, caused by a curling electric field that circulates around the loop. The induced emf is precisely the circulation of \vec{E} around the loop.

The minus sign in Faraday’s law (or the flux rule or whatever you call it) is called Lenz’s law. One way to remember it is this: The magnetic flux created *by* the induced current will tend to partly counteract the change in flux that induces the current. (If this were not the case, you could get a runaway effect by inducing a small current, whose field would induce a larger current, and so on.)

In every electrical circuit a changing current tends to induce a “back-emf” that partly counteracts the change. The back-emf is proportional to the time derivative of the current, and the constant of proportionality is called the inductance of the circuit, L :

$$(\text{back emf}) = -L\frac{dI}{dt}.$$

(The minus sign is again Lenz’s law.) The value of L for any circuit or circuit element is determined by the geometry. The inductance of a long solenoid is particularly simple to calculate, by combining this equation with Faraday’s law and the formula for the field inside a solenoid. A coil of wire stuck in a circuit specifically to create a large inductance is called an “inductor”.