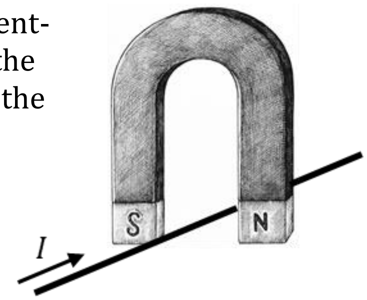
APPC, E & M: Unit C HW 5

Name: ______________________________
Hr: ___ Due at beg of hr on: __________

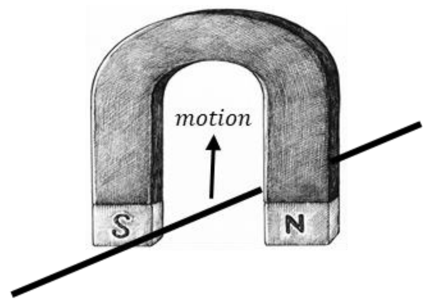
UC, HW5, P1
Reference Video: "Faraday's Law Basics (Part 1 of 3)"
YouTube, lasseviren1, ELECTROMAGNETIC INDUCTION & FARADAY'S LAW playlist

In the **motor effect**, electrical energy is converted into mechanical energy. A current-carrying wire is placed in a ***B*** field, and an $\boldsymbol{F_B}$ is exerted on the moving charges in the wire. Because the charges are contained within the wire, when the charges move, the wire moves: Voila! Electrical energy converted into mechanical.



A. With regard to the figure at right, in what direction will the wire move? (Hint: Use a RHR and find the direction of F_B.) UP DOWN

In the **generator effect**, mechanical energy is converted into electrical. A metal wire (NOT carrying a current, at the moment…) is placed in a ***B*** field. The wire is moved by some outside force: a hand cranking a generator, perhaps. The charges trapped within the wire must move along with it, and when charges move through a ***B*** field, an $\boldsymbol{F_B}$ arises. This $\boldsymbol{F_B}$ is at right angles to the original motion (which was due to the OUTSIDE force), and the $\boldsymbol{F_B}$ acts on the charges in the wire, and this produces…an INDUCED electric current $I_{induced}$. Voila! Mechanical energy converted into electrical.



B. When the metal wire is moved UPWARD in the ***B*** field, as shown in the picture above, determine the direction in which the induced current $I_{induced}$ will flow in the wire shown. Show your answer by drawing an arrow that points in the correct direction along the wire and labeling it $I_{induced}$.

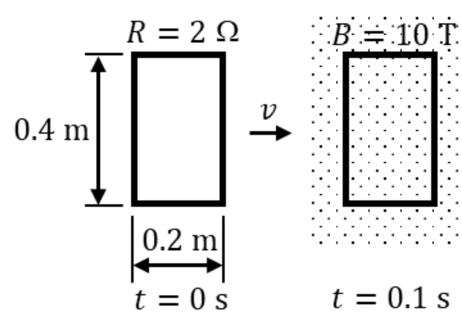
C. What is the name of the device – that has a needle attached to a coiled spring and a loop of wire – which is used to measure very tiny magnitudes (and directions, too, actually) of induced currents?

D. Suppose you have a coil and a magnet and wish to induce a current in the coil. WHAT TYPE of motion must there be, between the coil and the magnet?

E. We often focus on induced currents, but Faraday's law actually specifies *induced emfs* (or *induced voltages*). If a loop of metal wire is nearby, then induced emf will induce a current in it (according to Ohm's law). Anyway… Write the two, single-loop equations for Faraday's law, one for the instantaneous induced emf and the other for the average induced emf.

F. Write Faraday's law out in words. I'll start you off: "The emf induced around a loop of wire…"

G. A rectangular loop of metal enters a region of uniform magnetic field over a time of 0.1 s, as shown in the figure. Determine the magnitudes of (1) induced emf and (2) induced current over this time.

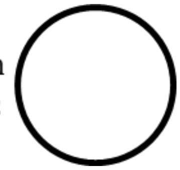


UC, HW5, P2

Reference Videos: (1) "Faraday's Law Basics (Part 2 of 3)"
(2) "Faraday's Law Basics (Part 3 of 3)"
YouTube, lasseviren1, ELECTROMAGNETIC INDUCTION & FARADAY'S LAW playlist

A. For the loop shown, the magnetic field varies with time according to

r = 12 cm
R = 2.0 Ω



$$B(t) = 26\cos(3\pi t)$$

Use Faraday's law to determine an expression for the emf in the loop as a function of time $\mathcal{E}$(t). Use a calculator and round the first part of your answer to two significant figures.

B. Use your Part A answer and information from the above figure to determine an expression for the current in the loop as a function of time I(t). Round your answer to two significant figures.

C. Write the Faraday's law equation for when we have multiple (i.e., N) loops.

D. Write the ENTIRE Faraday's law equation, for one loop.
(HINT: There should be TWO 'equals' signs in your answer.)

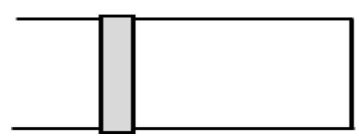
E. List here the three options we have in order to induce an emf $\mathcal{E}$ (and of course, a current I) in a loop.

1.

2.

3.

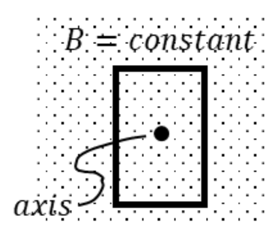
F. At right, the figure shows a metal wire bent into a ⊐ shape, along with a bar of metal that can slide left or right. Draw symbols into the figure to show that the entire apparatus is located in a uniform magnetic field that is directed INTO the page.



G. If the ***B*** field is constant, which part of your Part E answer (1, 2, or 3), will come into play when the metal bar slides one way or the other?

H. In the figure, use *hatching* (i.e., closely-spaced parallel lines, ≡, but usually *slanted*) to indicate the region we are focusing on, with regard to your Part G answer.

I. In the figure shown, if the ***B*** field is constant and uniform, explain why NO emf $\mathcal{E}$ is induced in the loop if it is rotated about the axis shown. If it helps, feel free to make reference to your Part E answers.



UC, HW5, P3
Reference Video: "Lenz's Law (Part 1 of 3)"
YouTube, lasseviren1, ELECTROMAGNETIC INDUCTION & FARADAY'S LAW playlist

A. Lenz's law says that the DIRECTION of the induced current will be to…

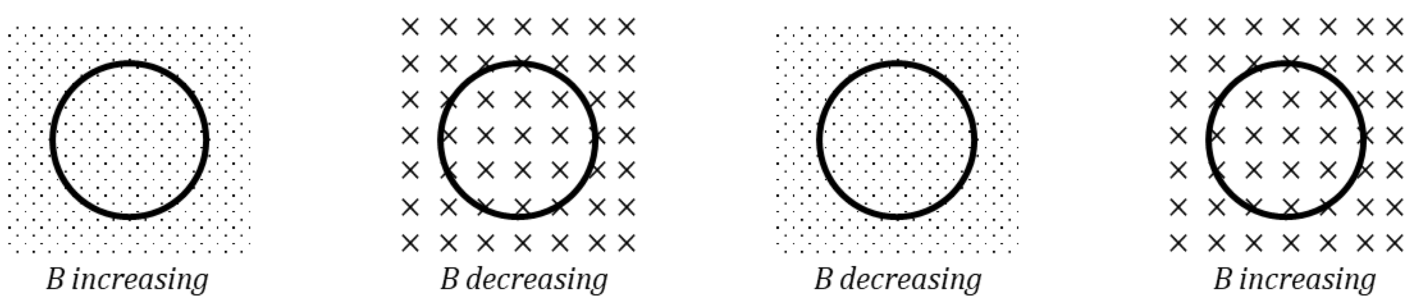
B. Just as mass resists changes in ____________________, Lenz's law says that conducting loops resist changes to the _________________________ __________ inside of them.

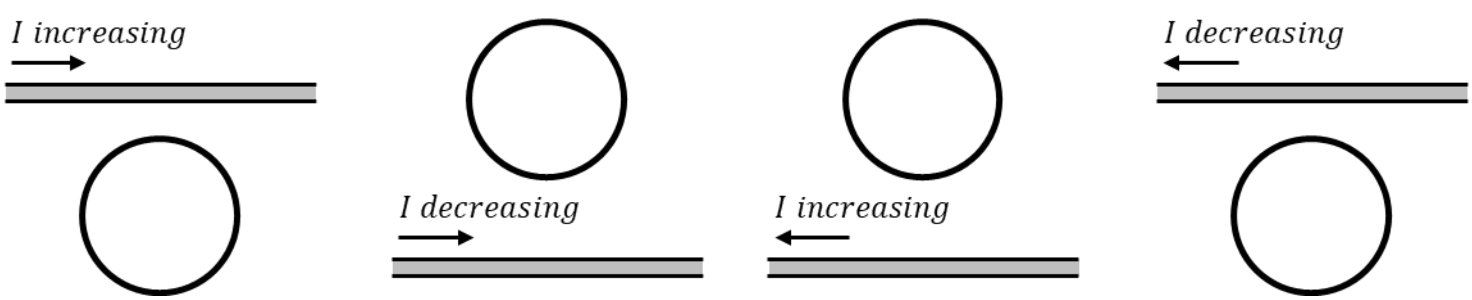
C. Lenz's law is essentially an expression of WHICH conservation law?

In this video, the narrator introduces our last right-hand rule (RHR), very similar to the one described previously in UC, HW3, P4. Here is how you use this one:

1. First, you have to have a conducting loop. Inside of this loop, the magnetic flux Φ_B must be changing, i.e., increasing or decreasing, AND you have to know which of those the Φ_B is doing. ☺
2. In accord with Lenz's law, you then figure out (by thinking!) which way the INDUCED ***B*** field inside the loop will "want" to point. Remember, the induced ***B*** field will "want" to point in such a way as to TRY TO OFFSET/MINIMIZE whatever change there was in the Φ_B that you identified in Step 1.
3. Point your right thumb in the direction the induced ***B*** field "wants" to point, as you deduced in Step 2.
4. Then, your right fingers curl in the direction of the current that has been induced in the loop. Done!

D. Use the RHR above to determine the direction of the induced current in each loop shown. Indicate each answer ABOVE the appropriate diagram, using one of the following symbols: I_{ind} ↻ or ↺ I_{ind}



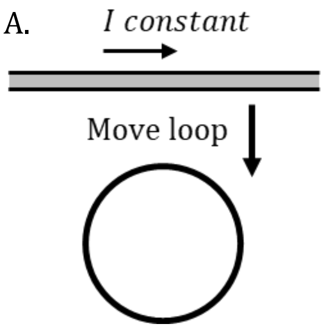


UC, HW5, P4

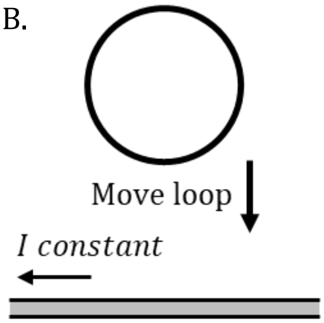
Reference Video: "Lenz's Law (Part 2 of 3)"
YouTube, lasseviren1, ELECTROMAGNETIC INDUCTION & FARADAY'S LAW playlist

Use the RHR described in HW5, P3 to determine the direction of the induced current in each loop shown. Indicate each answer INSIDE EACH LOOP using one of the following symbols: I_{ind} ⤸ or ⤹ I_{ind}

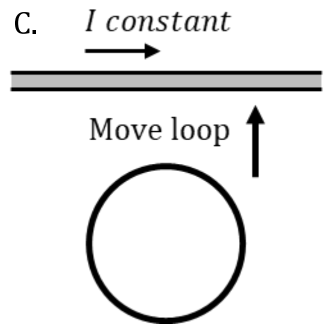
A.



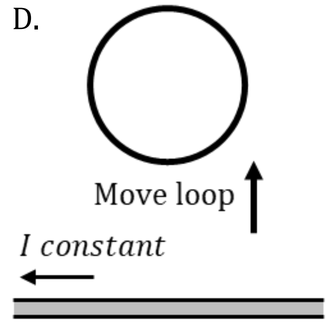
B.



C.

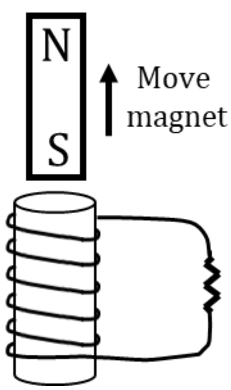


D.

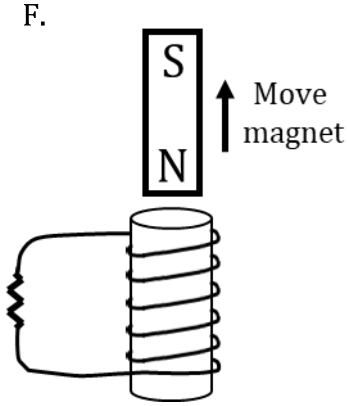


For Parts E-K, next to each resistor, draw an arrow to show the direction in which the I_{ind} flows.

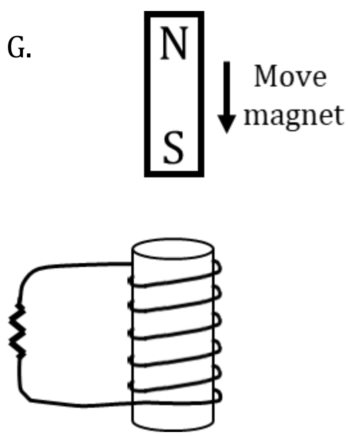
E.



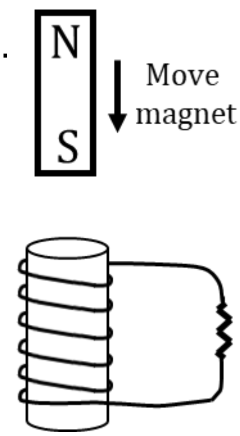
F.



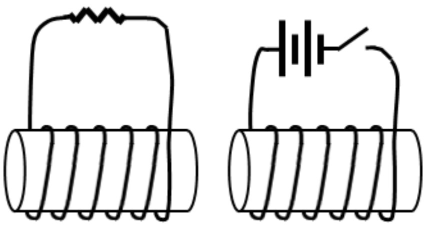
G.



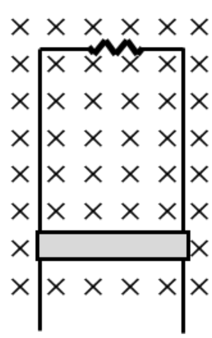
H.



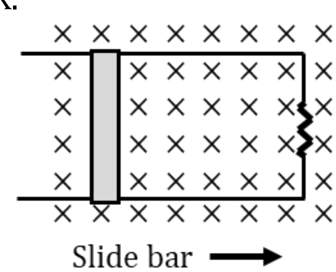
I.



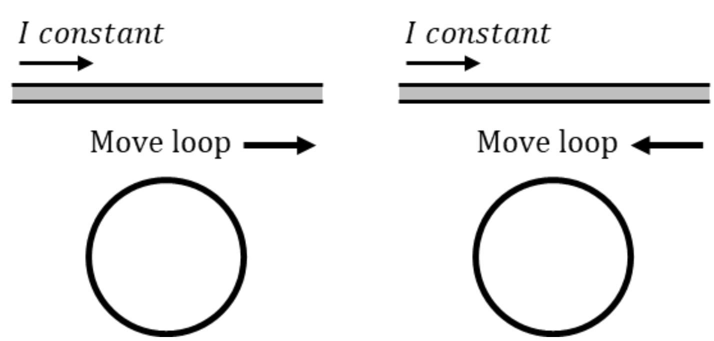
J.



K.

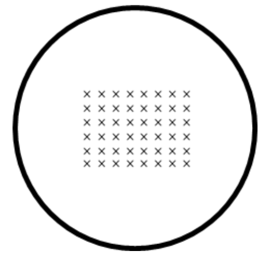


L. In the two cases at right, there is no induced emf $\mathcal{E}$ and no induced current I_{ind}. Why not?



UC, HW5, P5
Reference Videos: (1) “Lenz's Law (Part 3 of 3)”
(2) “Motional EMF and Application of Faraday's Law”
YouTube, lasseviren1, ELECTROMAGNETIC INDUCTION & FARADAY’S LAW playlist

A small region of ***B*** field is enclosed within a larger conducting loop.

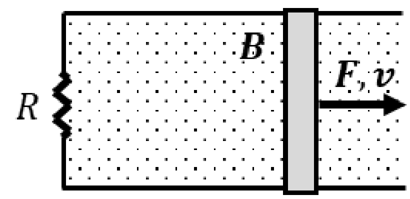


A. If the ***B*** field is increasing INTO the page, in which direction is there…

- …an induced emf $\mathcal{E}$ in the outer loop? CW CCW
- …an induced current I_{ind} in the outer loop? CW CCW

B. According to the narrator, WHAT HAPPENS such that the outer loop “knows” that an induced emf $\mathcal{E}$ should be brought into being at the location of the outer loop?

In the figure, the metal bar is sliding along at a constant speed ***v***, due to an applied force ***F***. The ***B*** field is directed out of the page and is constant. Note that there is a resistor *R* in the loop.



C. Let the dimensions of the loop-area be *x* and *L*, where *x* is the horizontal ‘base’ of the rectangle and *L* is the vertical ‘height’. Mark the dimensions *x* and *L* into the figure.

D. You recall that velocity is the time-derivative of…SOMETHING. After answering Part C, this something should now be shown in the figure. Figure out what the something is, and then, into the figure, next to ***v***, write “= *d something* / *dt*” (substituting the something in, obviously; DON’T write “something”).

E. As the bar slides, circle the direction of the… …induced electric field ***E*** CW CCW

…induced emf $\mathcal{E}$ CW CCW …induced current *I* CW CCW

F. Write the equation for magnetic flux Φ_B. This was your answer to Part Aiii of HW4, P4.

G. Modify your Part F answer, using variables shown in the figure, to obtain a simple equation for the magnetic flux Φ_B through the loop at the instant shown in the figure.

H. Write Faraday’s law for induced emf $\mathcal{E}$. This was your answer to Part C of HW5, P2.

I. Your Part H answer should have a *d*/*dt* in it. Now, “*d*/*dt*” the right side of your Part G answer and substitute the result into your Part H answer (where $N = 1$, because we have one loop) to get a simple expression for the magnitude (forget the sign, just make it +) of our induced emf $\mathcal{E}$.

J. Use your Part I answer and Ohm’s law to write an expression for the induced current *I*.

K. Way back in our unit on circuits, we derived that the rate at which electrical energy is turned into thermal energy in a resistor (which IS power) is given by $P = I^2R$. Use this equation, in conjunction with your Part J answer to derive an expression for *P* for this circuit.

L. Finally, back in Mechanics, we saw that $P = \vec{F} \cdot \vec{v}$. Use this equation, together with your Part K answer to write an equation for the force ***F*** needed to maintain the bar’s constant ***v***.