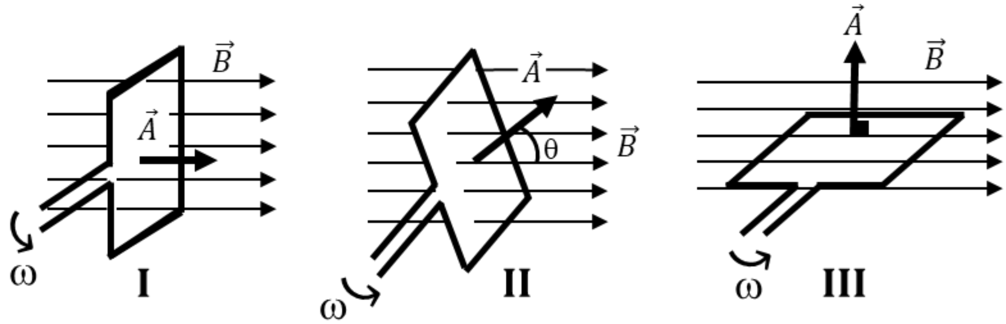
APPC, E & M: Unit C HW 6

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

UC, HW6, P1
Reference Video: "Basic Physics of the Generator"
YouTube, lasseviren1, ELECTROMAGNETIC INDUCTION & FARADAY'S LAW playlist

The figure shows a single metal loop being rotated at a constant angular speed ω in a uniform magnetic field ***B***. Note that the direction of the loop's area vector ***A*** is perpendicular to the plane of the loop.



A. Which Picture (I, II, or III) shows the…

…least magnetic flux Φ_B?

…most magnetic flux Φ_B?

B. What is θ for:

…Picture I?

…Picture III?

C. Write the simple equation for Φ_B that shows vector quantities, has a dot product, and has NO trig function in it.

D. Modify your Part C answer by eliminating the vector quantities and adding in a trig function.

E. Using the proper variables, write the simple equation that says 'angular displacement equals angular velocity multiplied by time'.

F. Substitute your Part E answer into your Part D answer.

G. Write the Faraday's law equation for when we have multiple (i.e., *N*) loops. This was your answer to HW5, P5, Part H.

H. Your Part G answer should indicate that something needs to be done to your Part F answer. Do that 'whatever it is' to your Part F answer, and then substitute that into your Part G answer to obtain a new expression for the induced voltage $\mathcal{E}$.

I. Based on your Part H answer, list here the four variables that can be increased in order to maximize the induced voltage $\mathcal{E}$. Also, use words to state what each variable represents.

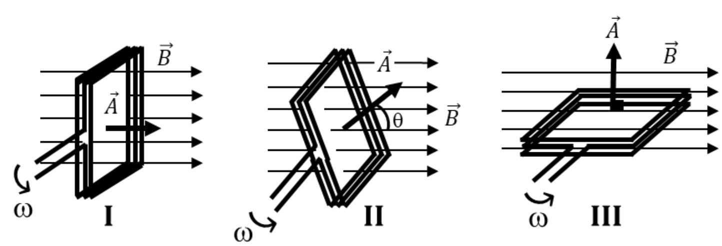
1.

2.

3.

4.

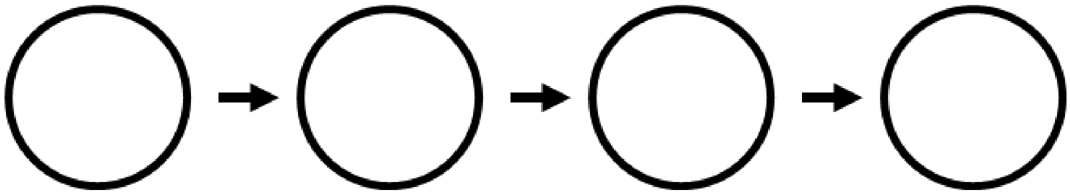
J. Which of the variables you listed in Part I is depicted differently in the figure at right, compared to the figure at the top of the page?



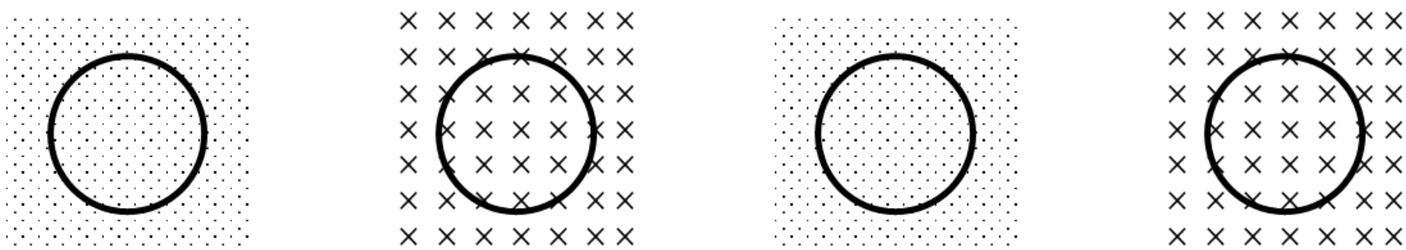
UC, HW6, P2

Reference Video: "Faraday's Law and Induced Electric Fields"
YouTube, lasseviren1, ELECTROMAGNETIC INDUCTION & FARADAY'S LAW playlist

A. In using Faraday's law for a loop of metal wire, the narrator lists four things that happen simultaneously, although it is helpful to think of them as happening in a linear sequence. In the circles below, list those four things that happen, and in the sequence mentioned in the video.



B. For EACH metal loop shown below, draw (and label as $\vec{E}$) FOUR electric field vectors to show the direction in which the induced electric field is directed, at various points on each loop. (This means you will need to draw a total of 4 x 4 = 16 vectors.)



B increasing *B decreasing* *B decreasing* *B increasing*

C. Write here the entire Faraday's law equation, for one loop.
(HINTS: There should be TWO 'equals' signs in your answer, and this answer should agree with your answer to Part D of HW5, P2.)

D. Write here the equation for finding voltage using a path integral of the electric field.
This answer is essentially the same as your Part C answer, way back in UA, HW7, P3.

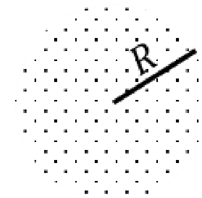
E. Describe the important way in which the integrals in your answers to Parts C and D differ, i.e., What does it mean, that the integrals are written as they are?

F. Your Part E answer has important implications with regard to the nature of the induced ***E*** field that you drew into your Part B answer and that you wrote out in your Part C answer. The video will help you complete the statements below, which describe ANY induced ***E*** field.

- Any induced electric field ***E*** is a ______________________________ electric field, which means that it is NOT caused by a buildup of…
- It is also a ______________________________ field, which means that the path integral of the field along any closed path is NOT equal to zero. This, in turn, means that forces exerted by this field have a strong tendency to increase the internal energy of material objects, i.e., generate heat.
- An induced electric field ***E*** can be said to exist at a particular location, even if there is NOT a material object at that location. (CIRCLE) TRUE FALSE

UC, HW6, P3
Reference Video: "Faraday's Law and Induced Electric Fields (Part II)"
YouTube, lasseviren1, ELECTROMAGNETIC INDUCTION & FARADAY'S LAW playlist

The figure shows a region of radius R that contains a $\boldsymbol{B}$ field that is increasing with time. Note that there is NOT a material loop at the region's edges; the $\boldsymbol{B}$ field simply stops at the points in space indicated by the boundary shown.



B increasing

A. If there WERE a metal loop around the region, in which direction would there be an induced current around the loop? (CIRCLE) CW CCW

B. If there ISN'T a metal loop, would there still be an induced $\boldsymbol{E}$ field at the region's boundaries (and elsewhere)? (CIRCLE) YES NO

C. Into the figure, draw (and label as $\vec{E}$) FOUR electric field vectors to show how the induced electric field is directed, at various points around the boundary.

Your task now is to derive equations for the $\boldsymbol{E}$ field at points where $r < R$ and also at points where $r > R$.

D. Write the entire Faraday's law equation, for one loop. (HINT: This answer should agree with your answer to Part C of HW6, P2.)

E. Write the simple equation for Φ_B that shows vector quantities, has a dot product, and has NO trig function in it.

F. Substitute your Part E answer into your Part D answer…then cross off the chunk of the equation that has NEITHER a derivative NOR an integral.

G. Into the figure, draw a Faradian loop having $r < R$.

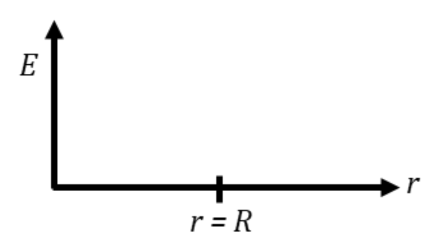
H. Suppose now that the $\boldsymbol{B}$ field is increasing at a constant rate γ, i.e., $\frac{dB}{dt} = \gamma$. Use this information, in conjunction with your new-and-improved Part F answer, to derive an expression for the $\boldsymbol{E}$ field at the location of $r < R$. NOTE: Ignore the (−) sign in the equation; you already provided information that took this into account when your drew the vectors in your Part C answer.

I. Into the figure, draw another Faradian loop having $r > R$.

J. Repeat the process of Part H, but now for $r > R$.

K. Show that, at the specific distance of R, your answers to Parts H and J yield exactly the same result.

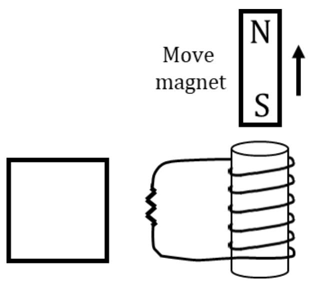
L. At right, draw a general graph that supports your answers to Parts H and J. Above each part of the curve, write a proportion that begins… "$E \propto$ …"



UC, HW6, P4
Reference Video: "Review of Induction, Faraday's Law, and Lenz's Law (Part I)"
YouTube, lasseviren1, ELECTROMAGNETIC INDUCTION & FARADAY'S LAW playlist

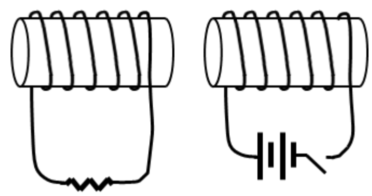
A. In which direction will current be induced in the square loop?

(circle) CW CCW

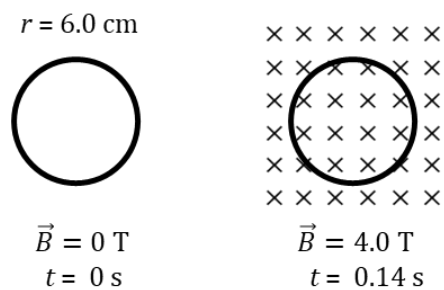


B. When the switch on the right is thrown, in which direction will induced current flow through the resistor on the left?

(circle) to the LEFT to the RIGHT



In the loop shown, no magnetic field is present, initially. In the figure to the right of the first, the same loop is shown 0.14 s later, when the magnetic field has increased (at a uniform rate) to a value of 4.0 T. The loop has a radius of 6.0 cm.

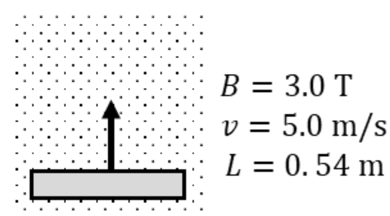


C. In which direction is there a current induced in the loop? (circle) CW CCW

D. Determine the magnitude of the induced emf in the loop.

A conducting bar is moving through a uniform ***B*** field at constant speed, as shown.

E. In which direction will there be a magnetic force $\boldsymbol{F_B}$ on the conventional charges in the bar? (circle) LEFT RIGHT

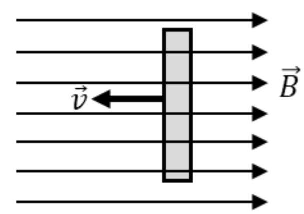


F. Justify your Part E answer. (i.e., How did you know that?)

G. Which portion of the bar will have a higher potential than the other portion? (circle) LEFT RIGHT

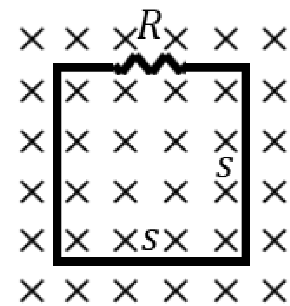
H. Determine the magnitude of the emf induced between the ends of the bar in the situation above.

I. For this last figure, explain why there is NO induced emf in the moving bar.
HINT: Your Part F answer may be of help.



UC, HW6, P5
Reference Videos: (1) "Review of Induction, Faraday's Law, and Lenz's Law (Part II)"
(2) "Review of Induction, Faraday's Law, and Lenz's Law (Part III)"
YouTube, lasseviren1, ELECTROMAGNETIC INDUCTION & FARADAY'S LAW playlist

The figure shows a square loop having side length s in a $\boldsymbol{B}$ field that varies with time according to the equation shown. There is a resistor R in the conducting loop.



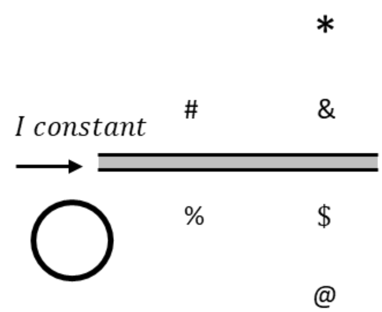
$$B(t) = B_o\, e^{-kt}$$

A. Following time $t = 0$, in which direction will there be an induced current in the loop? (circle) CW CCW

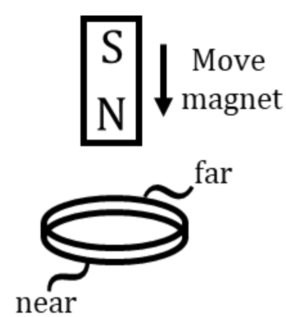
B. Based on the variables given, write an expression for the magnetic flux $\Phi_B(t)$ through the loop as a function of time.

C. Based on the variables given, write an expression for the current $I(t)$ through the loop as a function of time.

The figure directly at right shows a conducting wire carrying a constant current, as well as a conducting loop in the vicinity of the wire. In which direction, if any, will there be a current in the loop if the loop…



	…starts at location…	…and ends at location:	Circle your answer:		
D.	#	&	CW	CCW	no I_{induced}
E.	$	%	CW	CCW	no I_{induced}
F.	*	&	CW	CCW	no I_{induced}
G.	$	@	CW	CCW	no I_{induced}
H.	&	*	CW	CCW	no I_{induced}
I.	%	$	CW	CCW	no I_{induced}
J.	@	$	CW	CCW	no I_{induced}
K.	&	#	CW	CCW	no I_{induced}

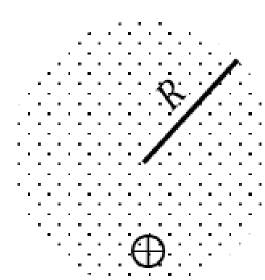


L. Into the figure at right, draw and label arrows around the conducting ring, showing the direction in which a current is induced around the ring.

The figure at lower right shows a region of magnetic field, which varies with time according to the equation shown. NOTE that the region has a radius R, but NO physical boundary.

M. Into the figure, draw and label an arrow showing the direction in which the induced $\boldsymbol{E}$ field points at ⊕, following $t = 0$.

N. ⊕ is a distance ¾ R from the center. Write an expression for the $\boldsymbol{E}$ field magnitude at that location.



$$B(t) = 3.0\, t^2$$