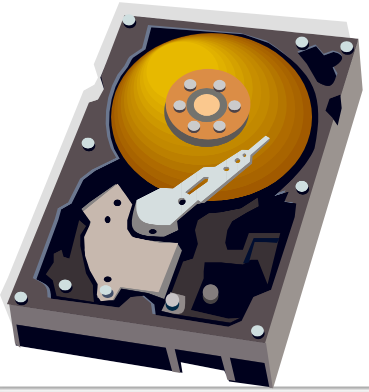
Electricity & Magnetism
Lecture 17

Today's Concept:

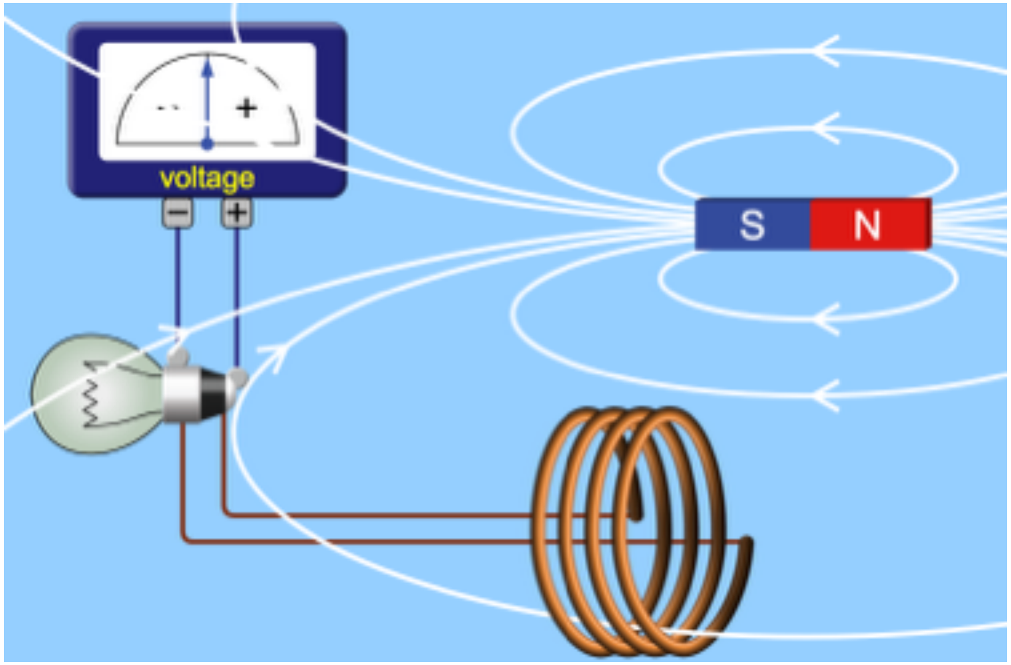


Faraday's Law

$$emf = \oint \vec{E} \cdot d\vec{\ell} = -\frac{d\Phi_B}{dt}$$

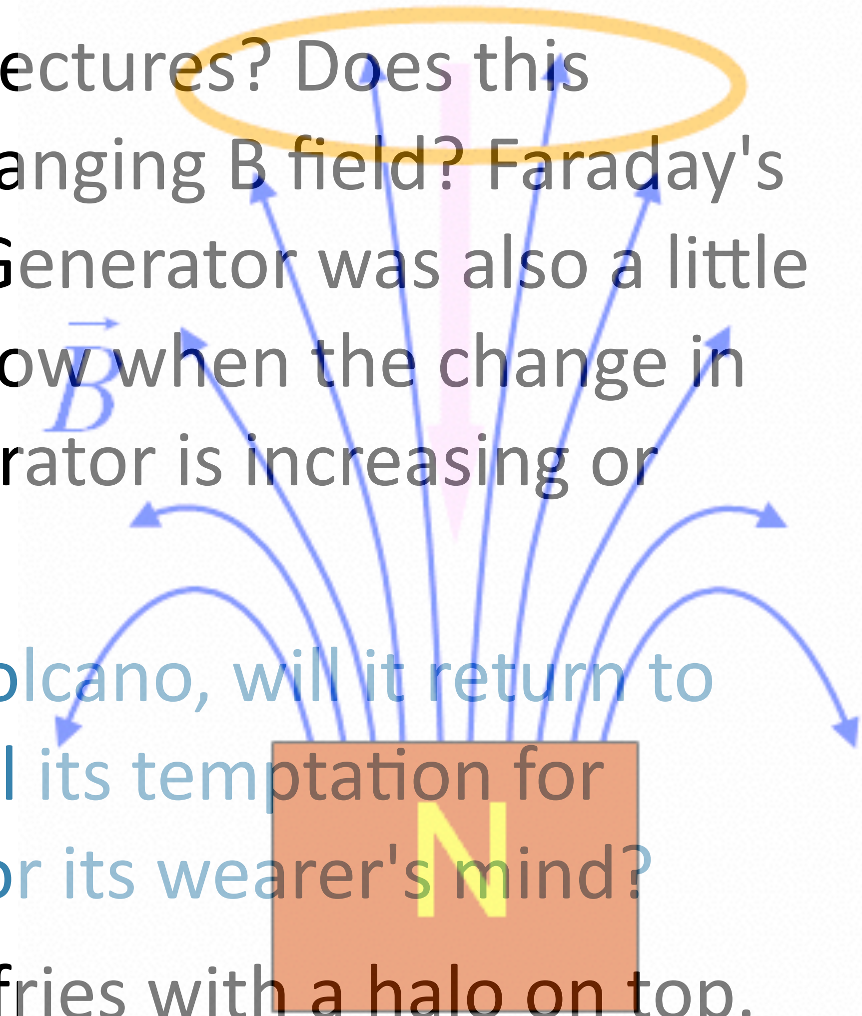
Simulation

https://phet.colorado.edu/sims/html/faradays-law/latest/faradays-law_en.html

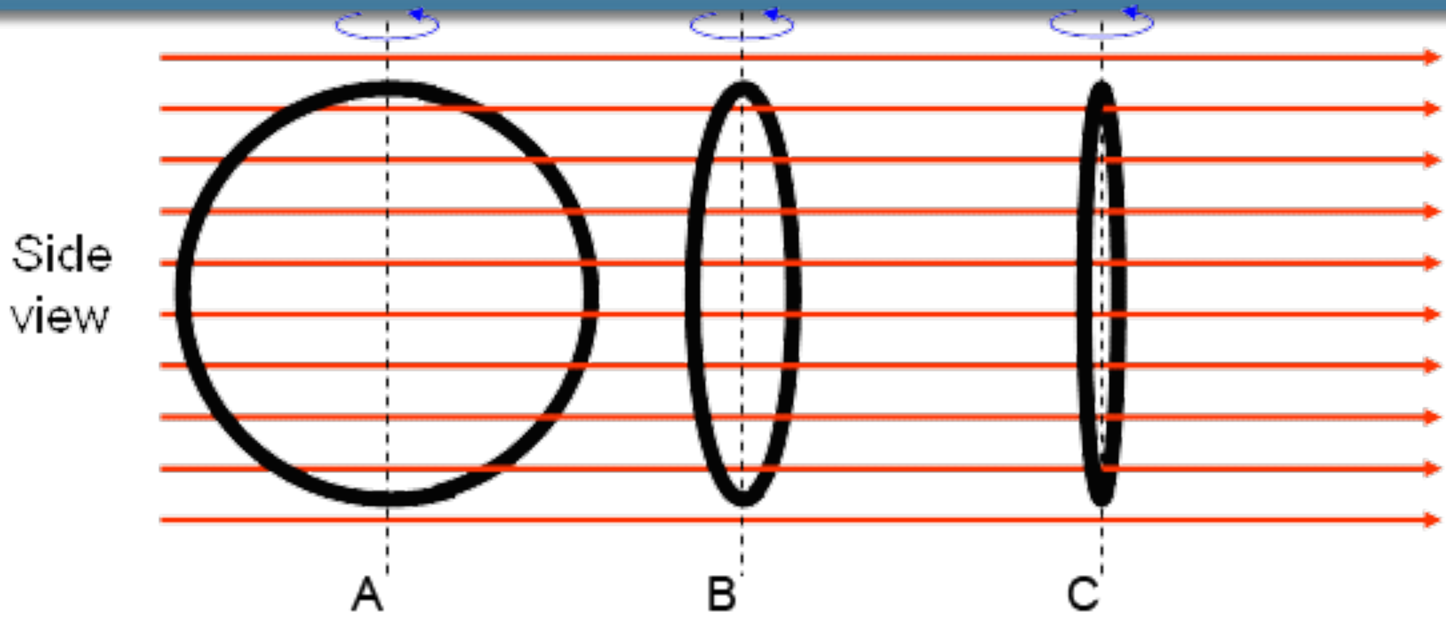


Stuff you said

- How is the 'induced' EMF different from the EMF discussed in previous prelectures? Does this induced EMF require a changing B field? Faraday's law being applied to the Generator was also a little confusing, how do you know when the change in magnetic flux in the Generator is increasing or decreasing?
- falling ring into magnet volcano, will it return to where it was made, or will its temptation for possession be too great for its wearer's mind?
- I like the blue Ncdonalds fries with a halo on top.



Your Question

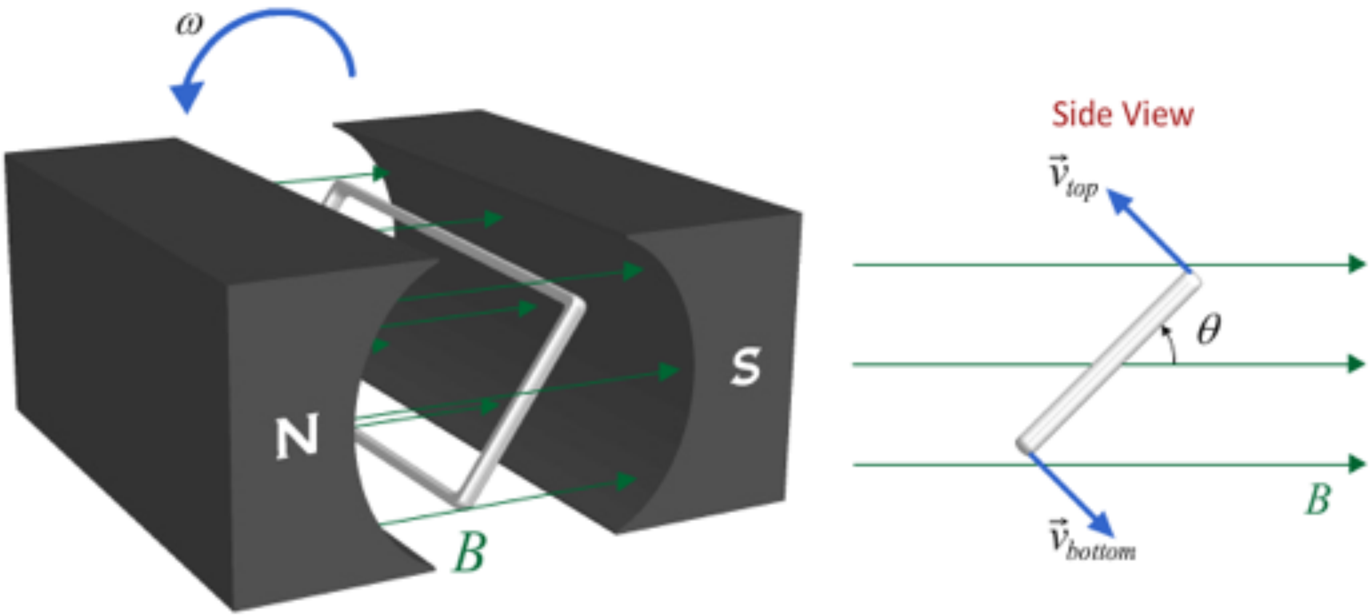


A circular wire loop is placed in a uniform magnetic field pointing to the right. The loop is rotated with constant angular velocity around a vertical axis (dashed line).

At which of the three times shown is the induced emf greatest?

Same as this

Only the loop is round.



Faraday's Law: $emf = \oint \vec{E} \cdot d\vec{\ell} = -\frac{d\Phi_B}{dt}$ where $\Phi_B \equiv \int \vec{B} \cdot d\vec{A}$

Looks scary but it's not – its amazing and beautiful!

↓

A changing magnetic flux produces an electric field.

↓

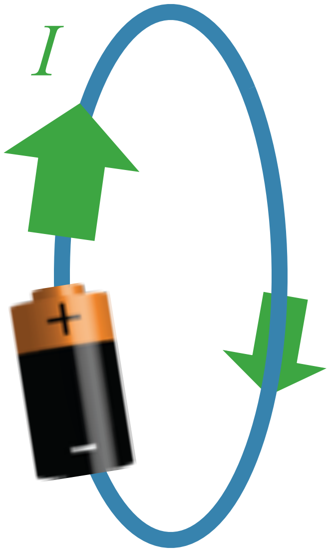
Electricity and magnetism are deeply connected.

Faraday's Law: $emf = \oint \vec{E} \cdot d\vec{\ell} = -\frac{d\Phi_B}{dt}$ where $\Phi_B \equiv \int \vec{B} \cdot d\vec{A}$

In Practical Words:

1) When the flux Φ_B through a loop changes, an *emf* is induced in the loop.

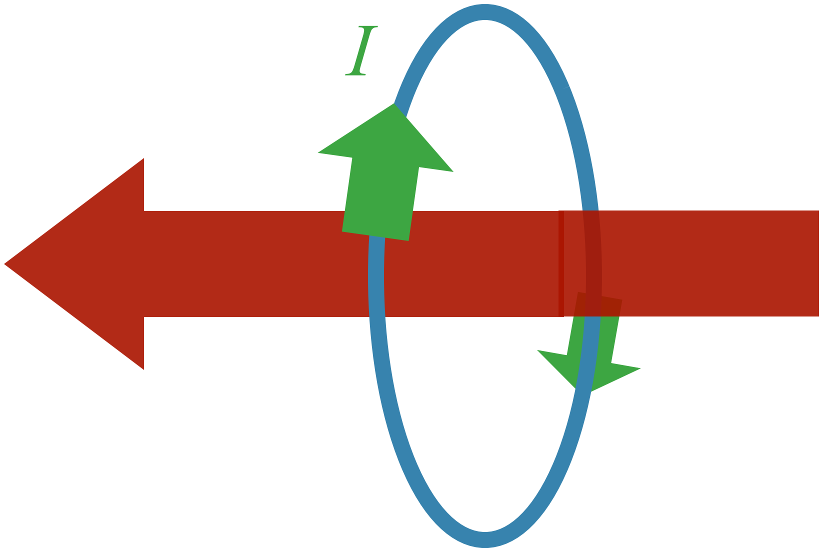
2) The *emf* will make a current flow if it can (like a battery).



Faraday's Law: $emf = \oint \vec{E} \cdot d\vec{\ell} = -\frac{d\Phi_B}{dt}$ where $\Phi_B \equiv \int \vec{B} \cdot d\vec{A}$

In Practical Words:

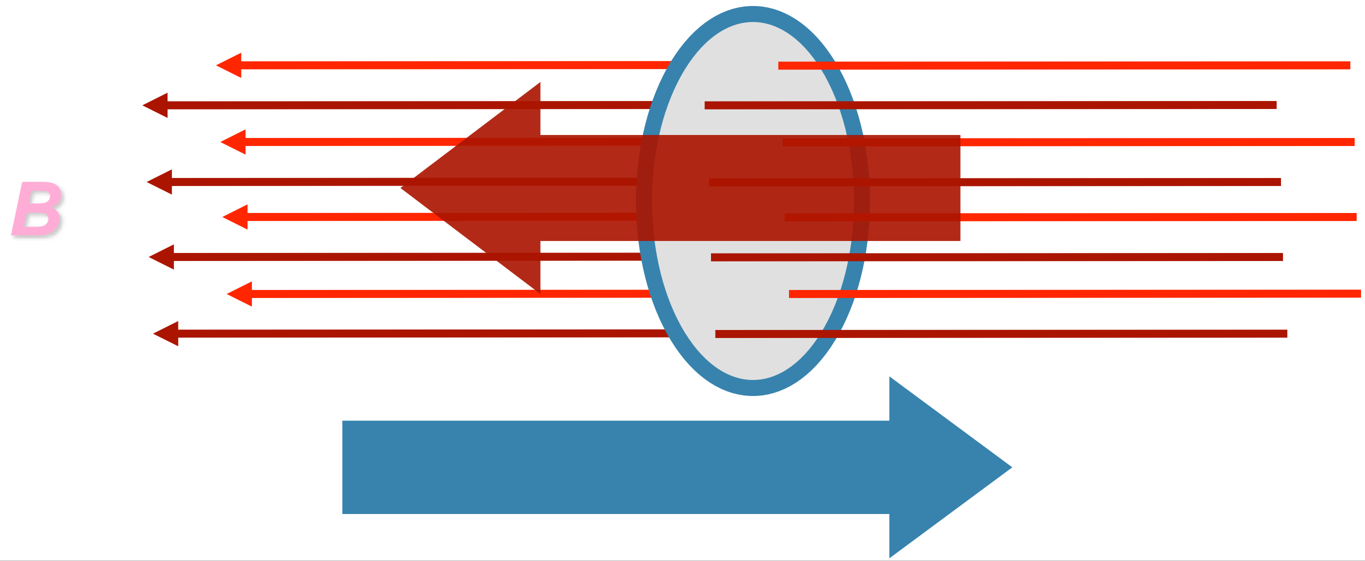
1) When the flux Φ_B through a loop changes, an *emf* is induced in the loop.
2) The *emf* will make a current flow if it can (like a battery).
3) The current that flows induces a new magnetic field.



Faraday's Law: $emf = \oint \vec{E} \cdot d\vec{\ell} = -\frac{d\Phi_B}{dt}$ where $\Phi_B \equiv \int \vec{B} \cdot d\vec{A}$

In Practical Words:

1) When the flux Φ_B through a loop changes, an *emf* is induced in the loop.
2) The *emf* will make a current flow if it can (like a battery).
3) The current that flows induces a new magnetic field.
4) The new magnetic field opposes the change in the original magnetic field that created it. (**Lenz' Law**)



Faraday's Law: $emf = \oint \vec{E} \cdot d\vec{\ell} = -\dfrac{d\Phi_B}{dt}$ where $\Phi_B \equiv \int \vec{B} \cdot d\vec{A}$

Executive Summary:

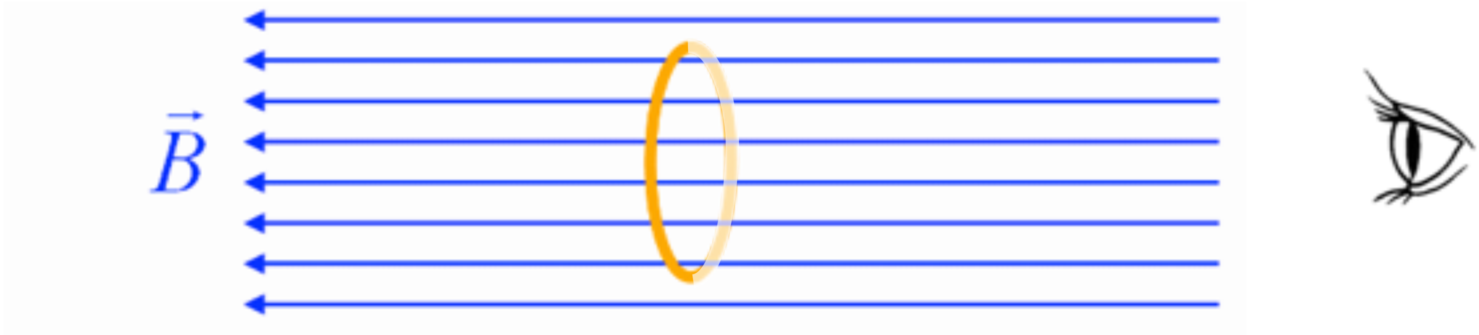
$emf \longrightarrow$ current $\longrightarrow$ field

a) induced only when flux is changing

b) opposes the change

Clicker Question

A copper loop is placed in a uniform magnetic field. You are looking from the right



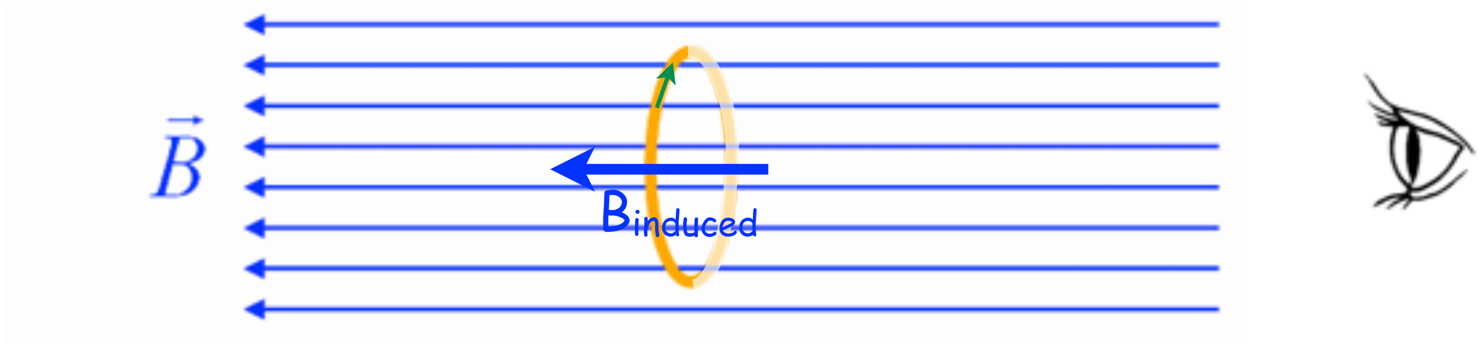
Suppose the loop is moving to the right, The current induced in the loop is

A) zero

B) clockwise

C) counterclockwise

A copper loop is placed in a uniform magnetic field. You are looking from the right



The induced B tries to boost up the decreasing external field.

Now suppose the loop is stationary and that the magnetic field is *decreasing*. The current induced in the loop is

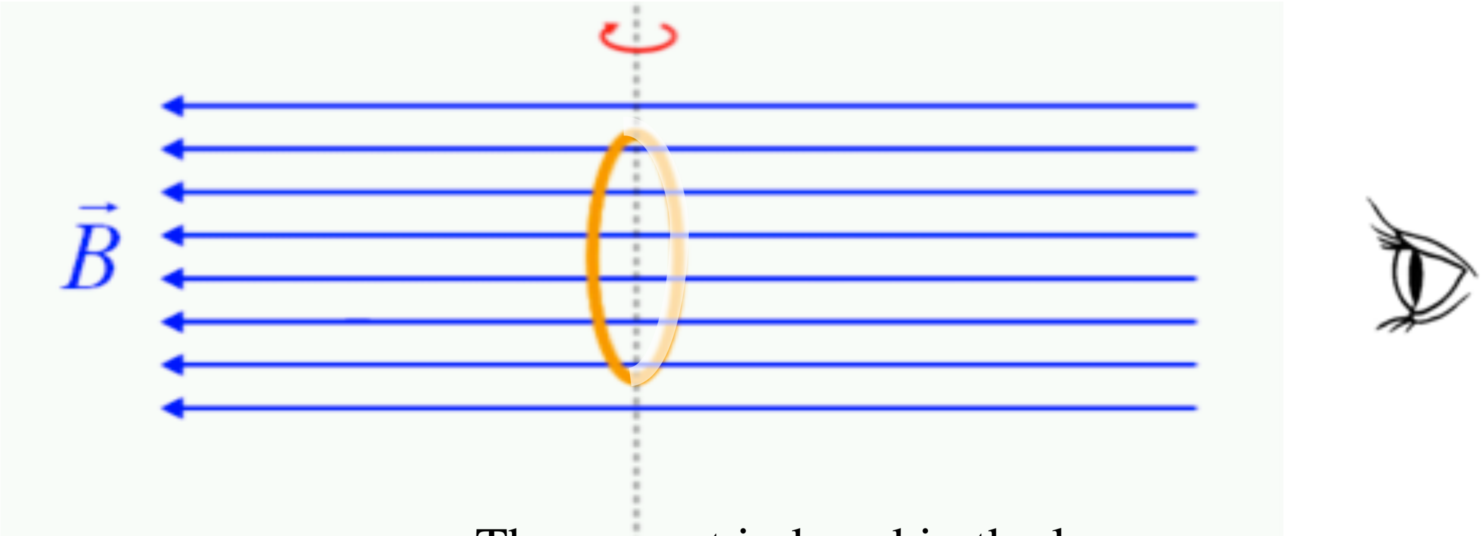
A) zero

B) clockwise

C) counterclockwise

CheckPoint 6

Suppose the loop is spun around a vertical axis, and that it makes on complete revolution every second



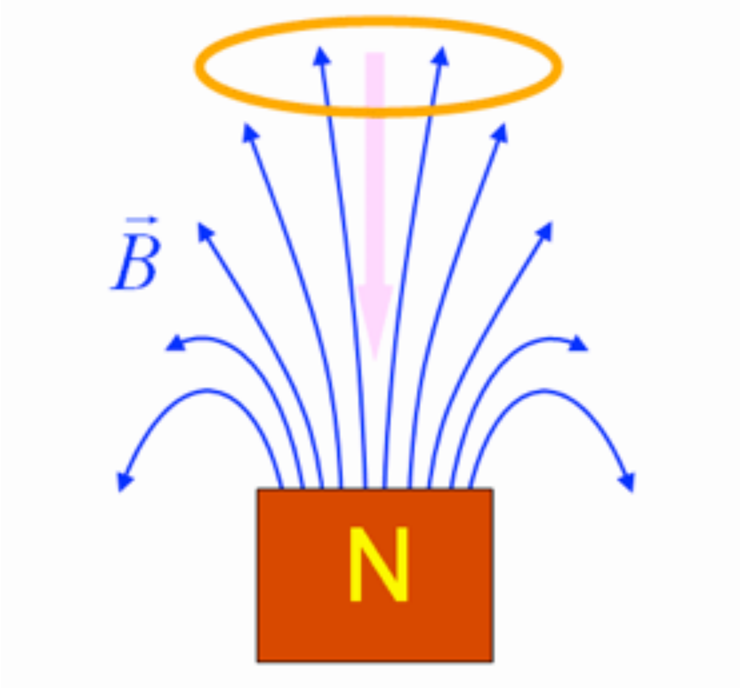
The current induced in the loop

A) is zero

B) changes once per second

C) changes twice per second

A horizontal copper ring is dropped from rest directly above the north pole of a permanent magnet.



Will the acceleration |*a*| of the falling ring in the presence of the magnet be any different than it would have been under the influence of just gravity?

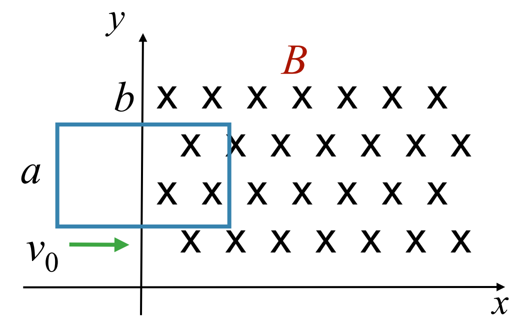
A) $|a| > g$

B) $|a| = g$

C) $|a| < g$

Calculation

A rectangular loop (height = a, length = b, resistance = R, mass = m) coasts with a constant velocity v_0 in $+x$ direction as shown. At $t = 0$, the loop enters a region of constant magnetic field B directed in the $-z$ direction.



What is the direction and the magnitude of the force on the loop when half of it is in the field?

Conceptual Analysis

Once loop enters B field region, flux will be changing in time

Faraday's Law then says emf will be induced

Strategic Analysis

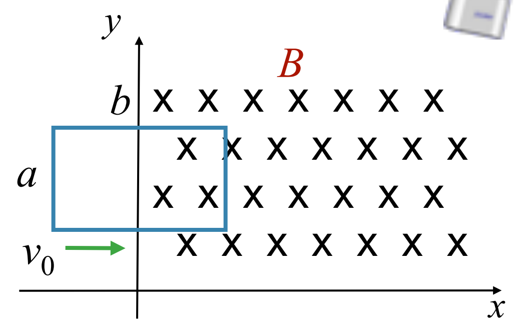
Find the emf

Find the current in the loop

Find the force on the current

Calculation

A rectangular loop (height = a, length = b, resistance = R, mass = m) coasts with a constant velocity v_0 in $+x$ direction as shown. At $t = 0$, the loop enters a region of constant magnetic field B directed in the $-z$ direction.



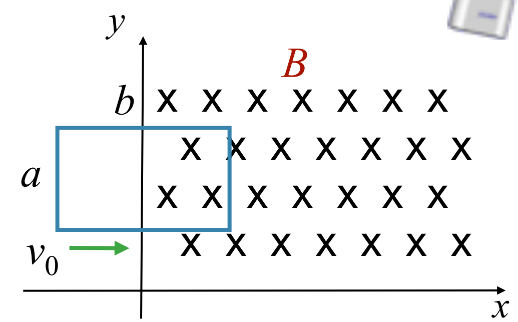
What is the magnitude of the emf induced in the loop just after it enters the field?

$$emf = -\frac{d\Phi_B}{dt}$$

A) $\mathcal{E} = Babv_0^2$ B) $\mathcal{E} = \frac{1}{2} Bav_0$ C) $\mathcal{E} = \frac{1}{2} Bbv_0$ D) $\mathcal{E} = Bav_0$ E) $\mathcal{E} = Bbv_0$

Calculation

A rectangular loop (height = a, length = b, resistance = R, mass = m) coasts with a constant velocity v_0 in $+x$ direction as shown. At $t = 0$, the loop enters a region of constant magnetic field B directed in the $-z$ direction.



What is the direction of the current induced in the loop just after it enters the field?

$$emf = -\frac{d\Phi_B}{dt}$$

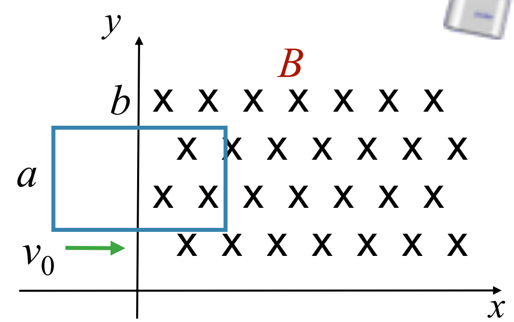
A) clockwise

B) counterclockwise

C) no current is induced

Calculation

A rectangular loop (height = a, length = b, resistance = R, mass = m) coasts with a constant velocity v_0 in $+x$ direction as shown. At $t = 0$, the loop enters a region of constant magnetic field B directed in the $-z$ direction.



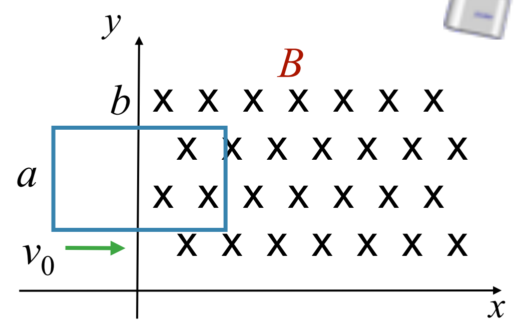
$$emf = -\frac{d\Phi_B}{dt}$$

What is the direction of the net force on the loop just after it enters the field?

A) $+y$ B) $-y$ C) $+x$ D) $-x$

Calculation

A rectangular loop (height = a, length = b, resistance = R, mass = m) coasts with a constant velocity v_0 in $+x$ direction as shown. At $t = 0$, the loop enters a region of constant magnetic field B directed in the $-z$ direction.



What is the magnitude of the net force on the loop just after it enters the field?

$\vec{F} = I\vec{L} \times \vec{B}$ $\mathcal{E} = Bav_0$ $emf = -\frac{d\Phi_B}{dt}$

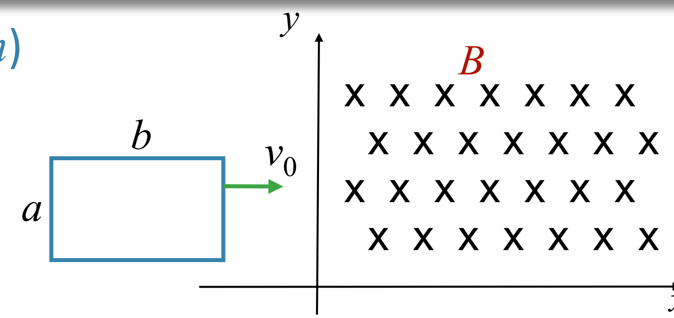
A) $F = 4aBv_oR$ B) $F = a^2Bv_oR$ C) $F = a^2B^2v_o^2/R$ D) $F = a^2B^2v_o/R$

$$F = \frac{\mathcal{E}}{R}aB$$

$$F = \frac{Bav_0}{R}aB = \frac{a^2B^2v_0}{R}$$

Follow Up

A rectangular loop (sides = a,b, resistance = R, mass = m) coasts with a constant velocity v_0 in $+x$ direction as shown. At $t = 0$, the loop enters a region of constant magnetic field B directed in the $-z$ direction.



$t = dt$: $\mathcal{E} = Bav_0$

What is the velocity of the loop when half of it is in the field?

Which of these plots best represents the velocity as a function of time as the loop moves from entering the field to halfway through ?