
PH 220
Lance Nelson

Summary

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an electric field?

How do you create
a magnetic field?

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How do you create a magnetic field?

$$\vec{B} = \frac{\mu_0}{4\pi}\frac{q\vec{v} \times \hat{r}}{r^2}$$

$$\vec{B} = \frac{\mu_0}{4\pi}\frac{I\vec{\Delta s} \times \hat{r}}{r^2}$$

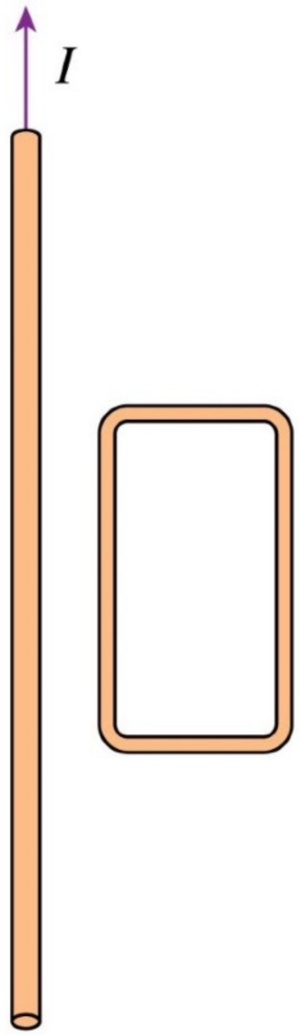
Lenz's Law

There is an induced current in a closed, conducting loop *if and only if the magnetic flux through the loop is changing*. The direction of the induced current *is such that the induced magnetic field opposes the change in flux*.

Question #38

The current in the straight wire is decreasing. Which is true?

A. There is a counterclockwise induced current in the loop.
B. There is no induced current in the loop.
C. There is a clockwise induced current in the loop.



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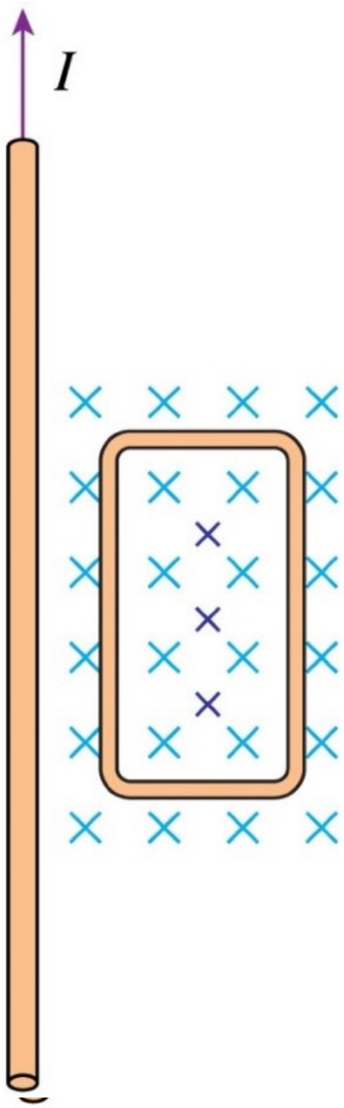
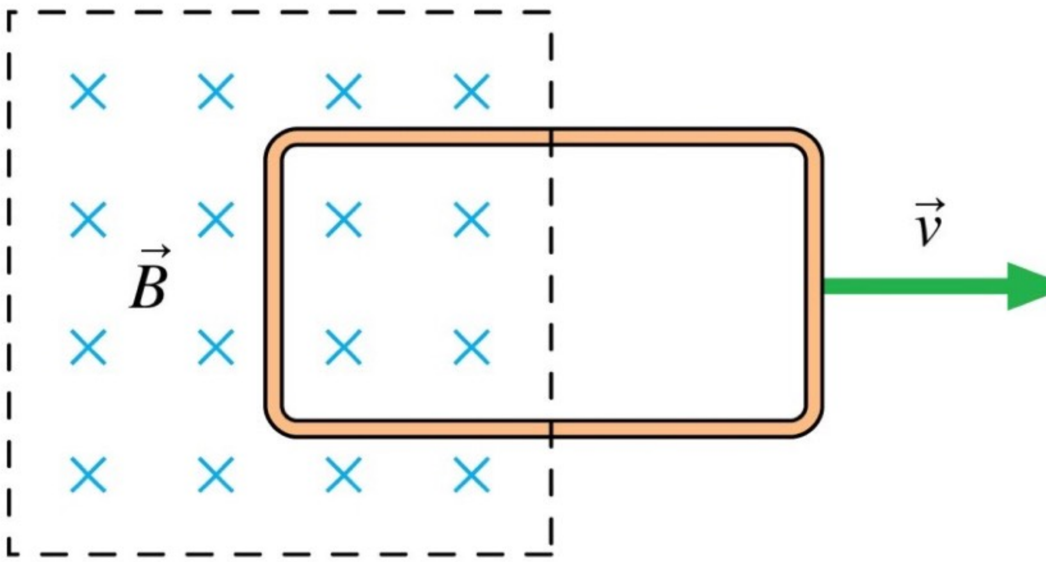


Question #39

The magnetic field is confined to the region inside the dashed lines; it is zero outside. The metal loop is being pulled out of the magnetic field. Which is true?



C. There is a counterclockwise induced current in the loop.
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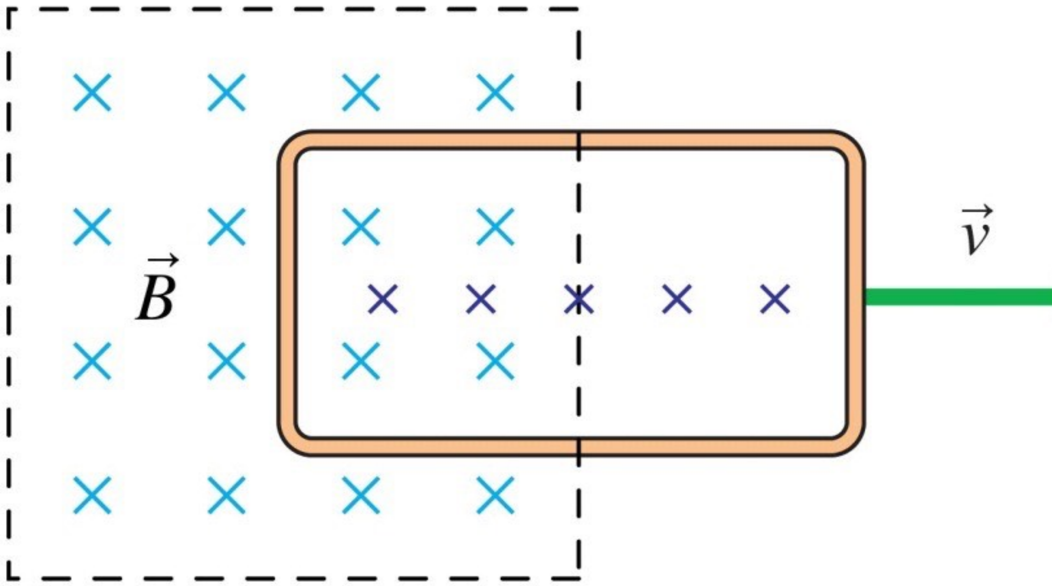

C. There is a counterclockwise induced current in the loop.
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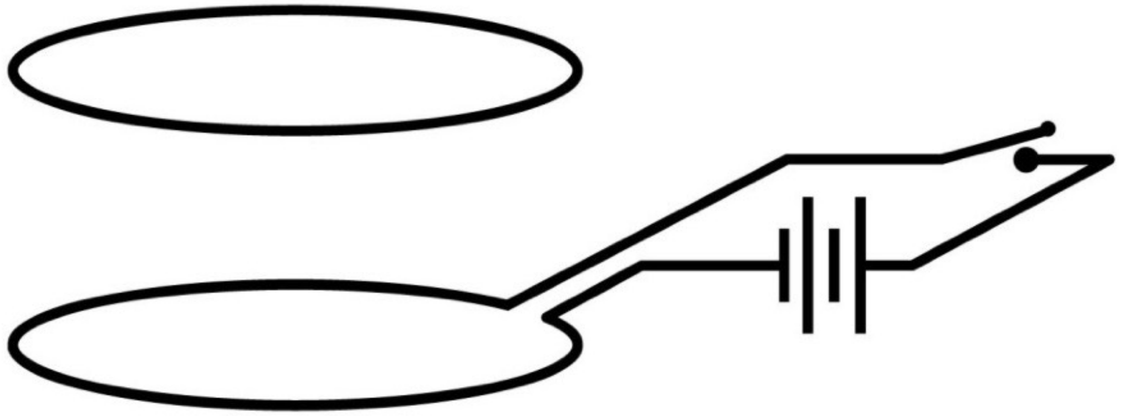
Question #40

Immediately after the switch is closed, the lower loop exerts ____ on the upper loop.

A. a torque
B. no force
C. a downward force
D. an upward force



Faraday's Law

The magnitude of the potential difference is given by Faraday's law.....

$$\mathcal{E} = |\frac{d\Phi}{dt}|$$

The direction is given by Lenz's law...

$$\vec{B} = \frac{\mu_0}{4\pi} \frac{q\vec{v} \times \hat{r}}{r^2}$$

$$\Phi = \vec{A} \cdot \vec{B}$$

$$\mathcal{E} = |\frac{d\Phi}{dt}|$$

$$\vec{F} = I\vec{l} \times \vec{B}$$

$\vec{\mu} = (AI$, from the south pole to the north pole)

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$\boxed{2}$

$$\vec{B} = \frac{\mu_0}{4\pi} \frac{q\vec{v} \times \hat{r}}{r^2}$$

$\boxed{7}$

$$\Phi = \vec{A} \cdot \vec{B}$$

$$\vec{F} = q\vec{v} \times \vec{B} \boxed{6}$$

$$\vec{\tau} = \vec{\mu} \times \vec{B} \quad \boxed{3}$$

$$\oint \vec{B} \cdot d\vec{s} = \mu_0 I$$

$\boxed{9}$

$\boxed{1}$

$$\mathcal{E} = \left|\frac{d\Phi}{dt}\right|$$

$$\vec{B} = \frac{\mu_0}{4\pi} \frac{I\vec{\Delta s} \times \hat{r}}{r^2}$$

$\boxed{5}$

$$\vec{F} = I\vec{l} \times \vec{B}$$

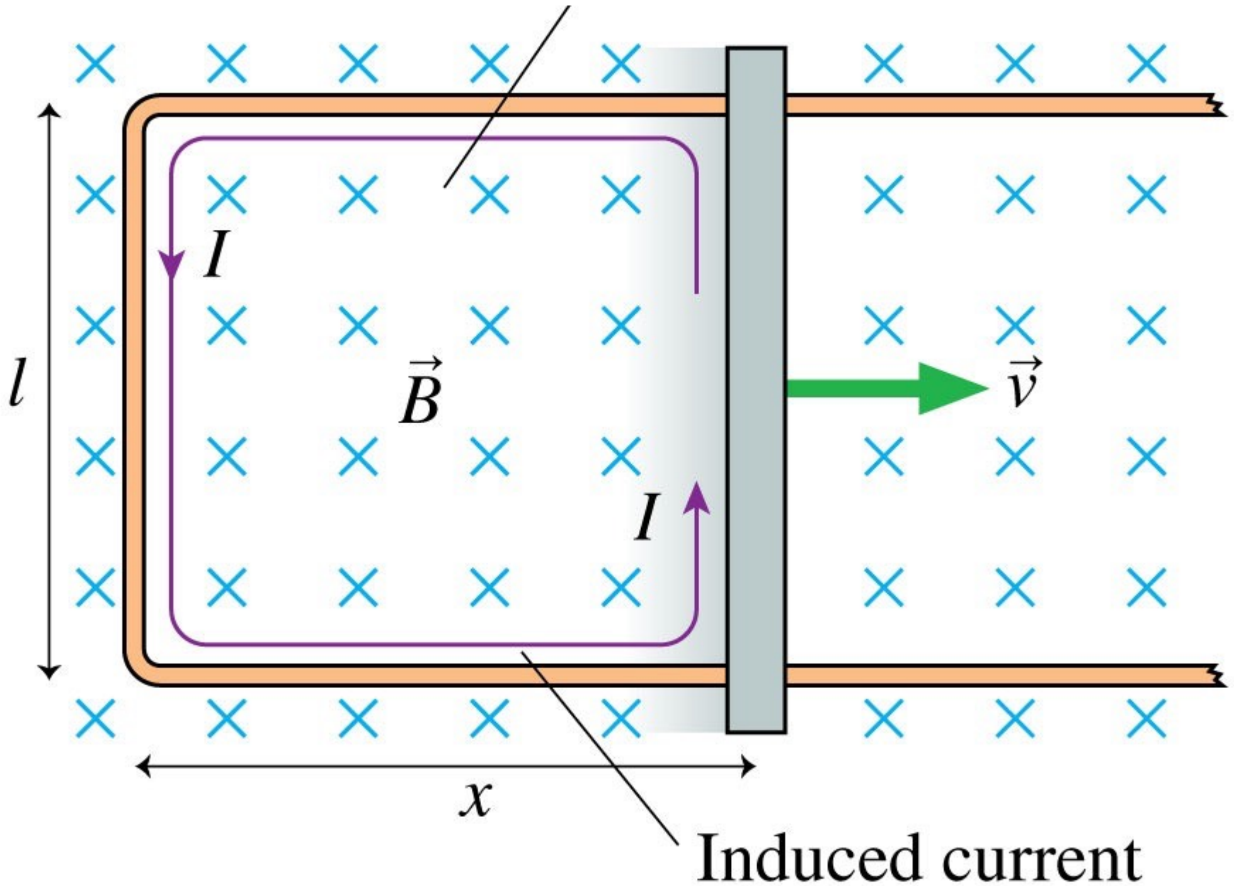
$\boxed{4}$

$\vec{\mu} = (AI,$ from the south pole to the north pole$)$

$\boxed{8}$

Let's try it out

$$\mathcal{E} = \left|\frac{d\Phi}{dt}\right|$$



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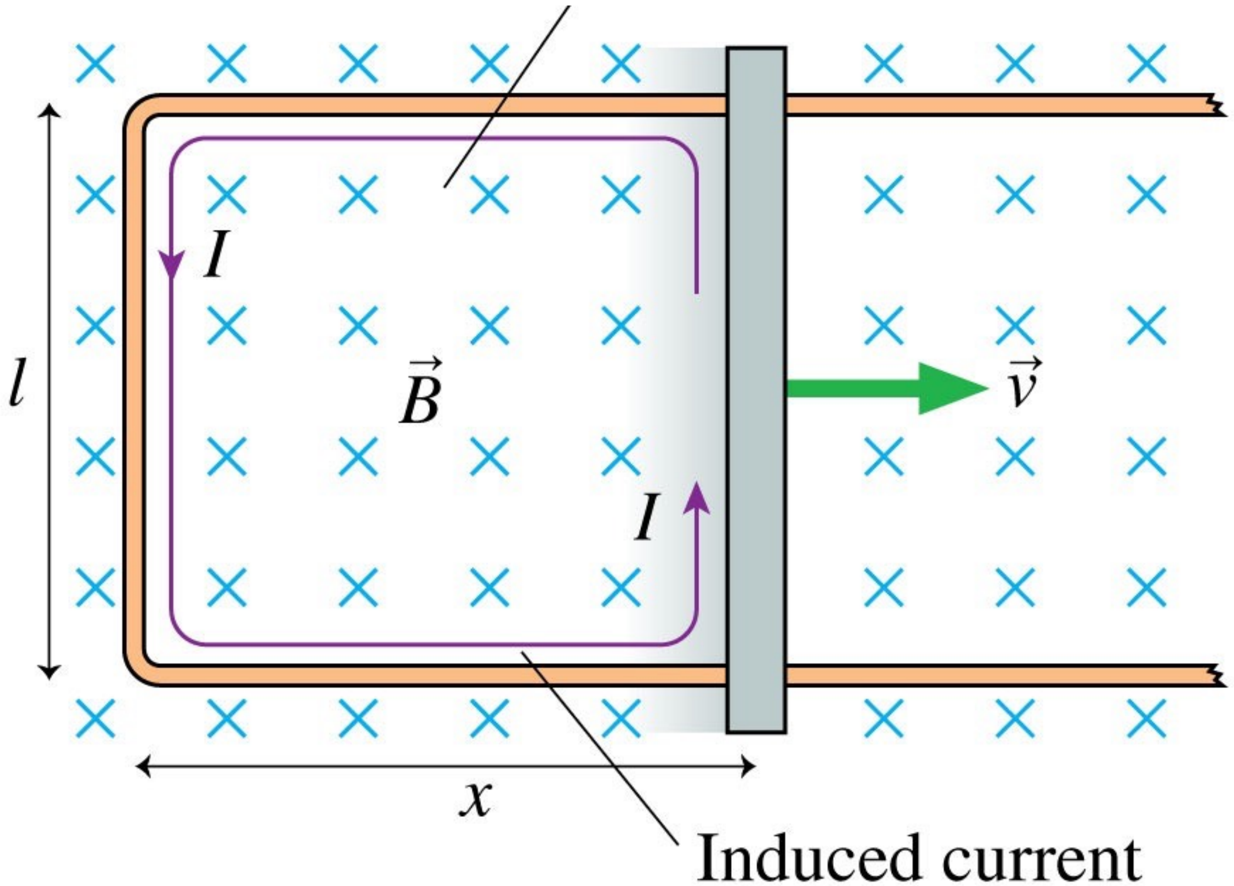

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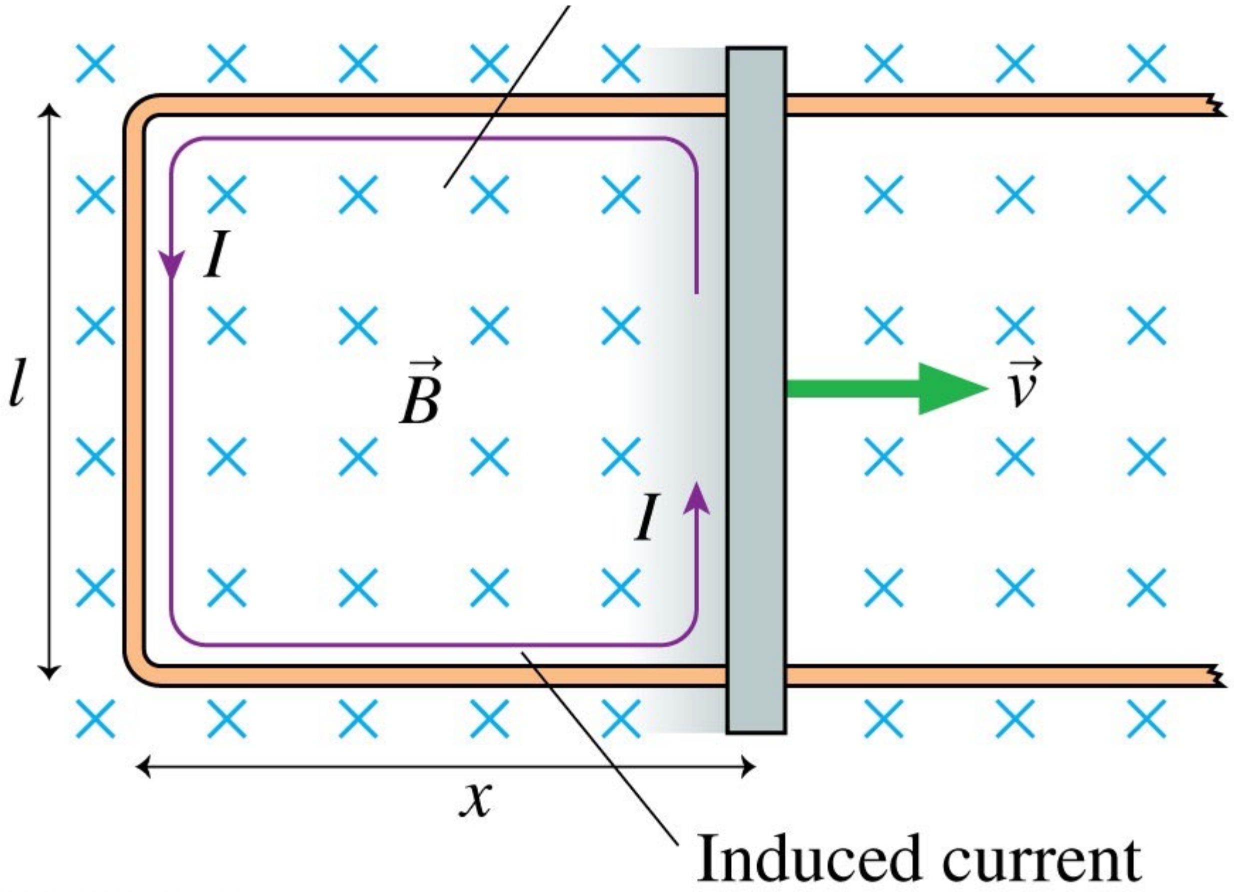

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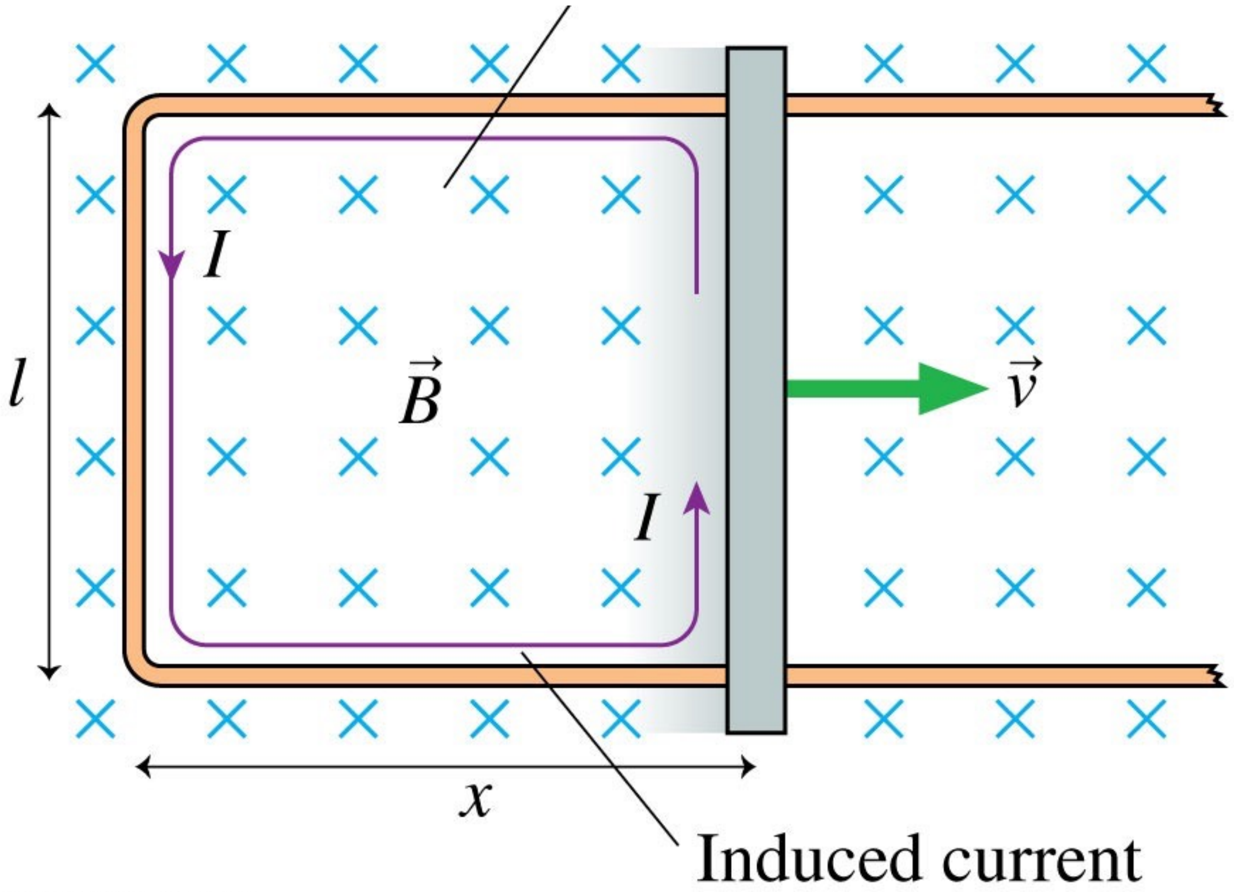

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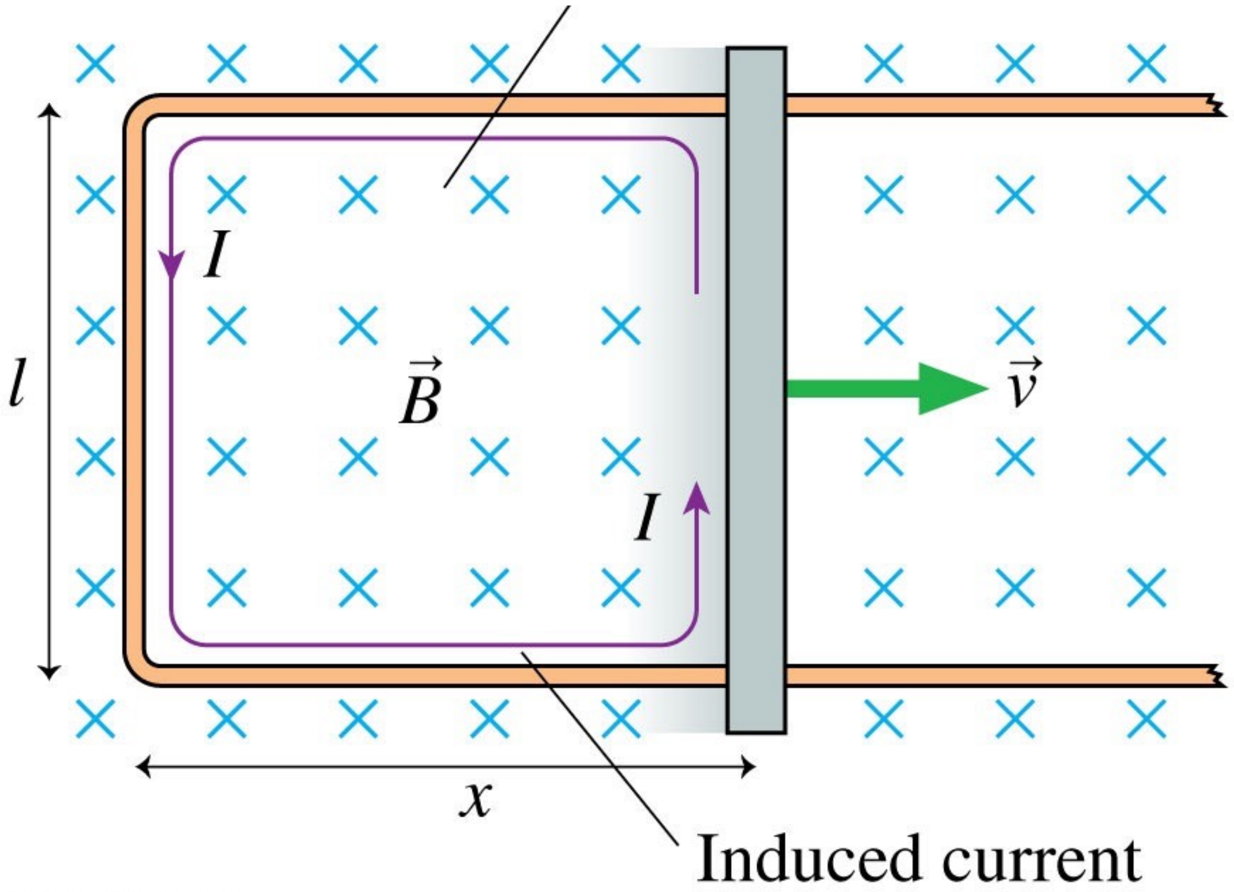
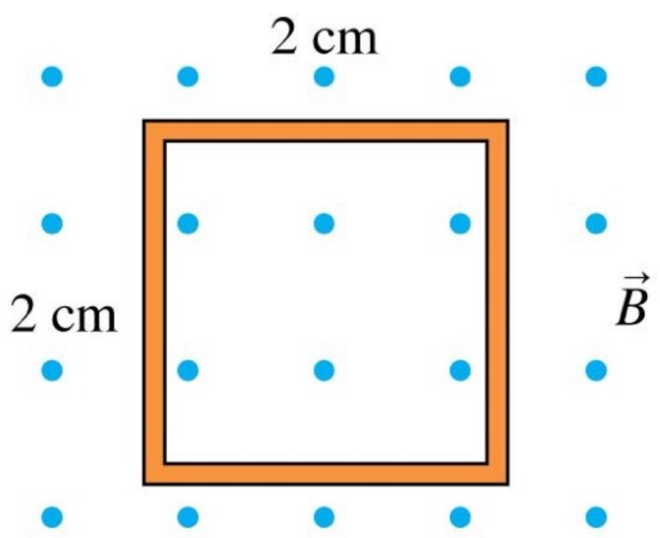
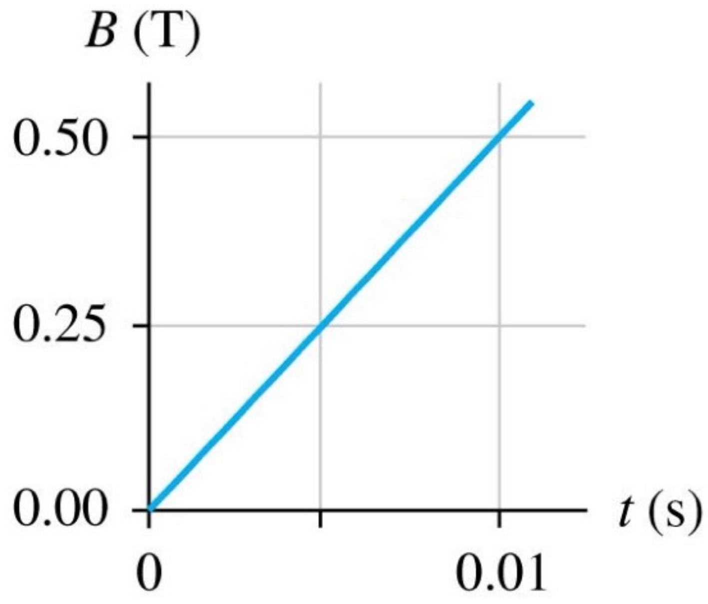


Question #41

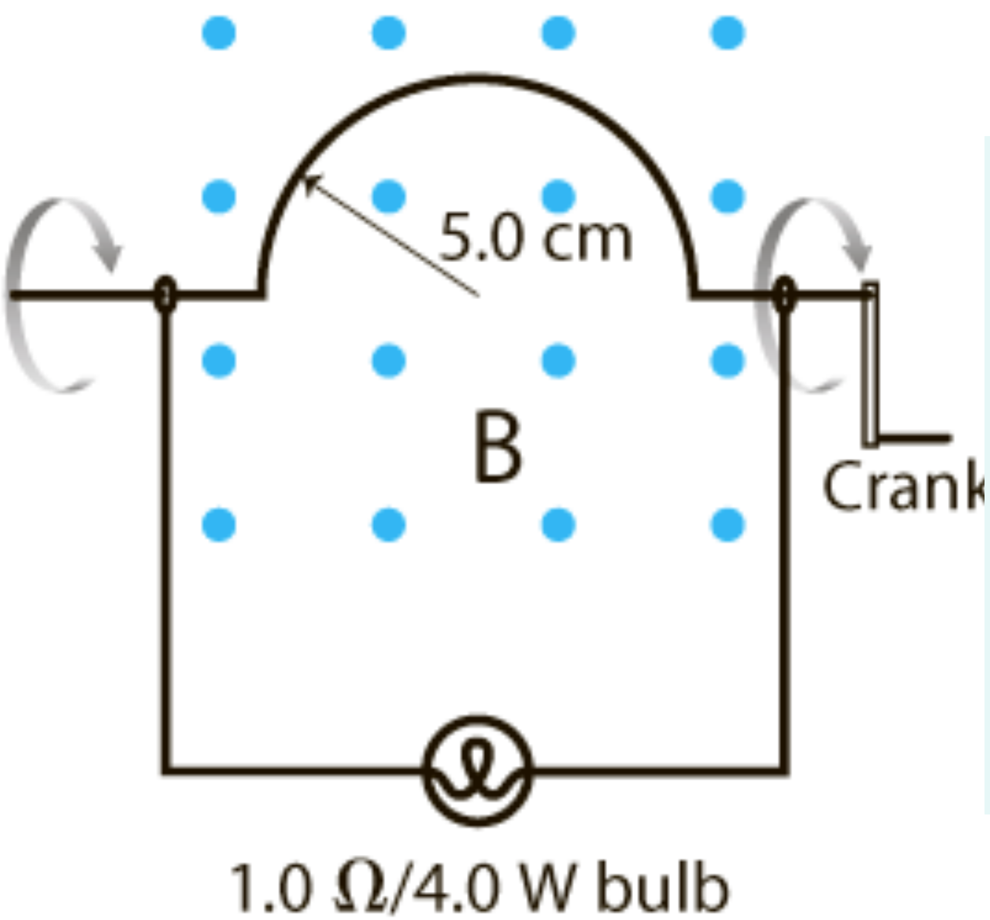
The induced emf around this loop is

A. 0.2 V.
B. 0.5 V.
C. 2 V.
D. 50 V.
E. 200 V.





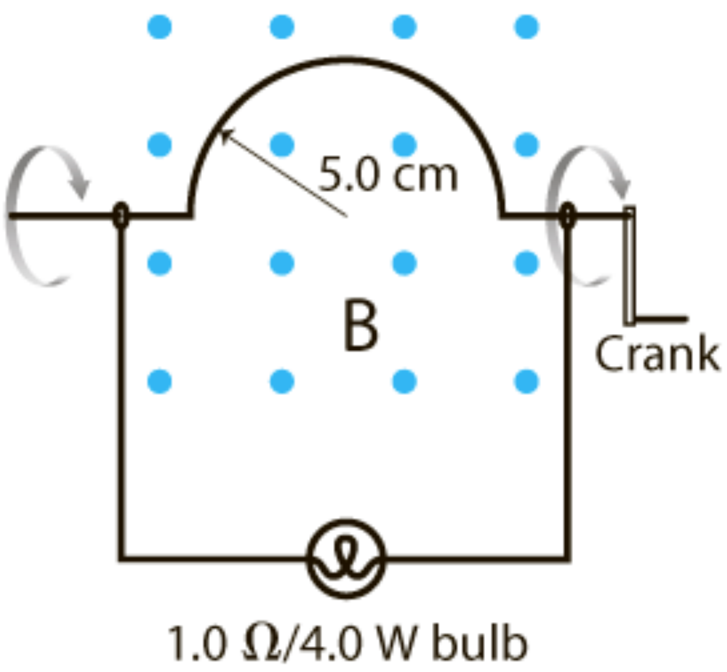
Homework style problem



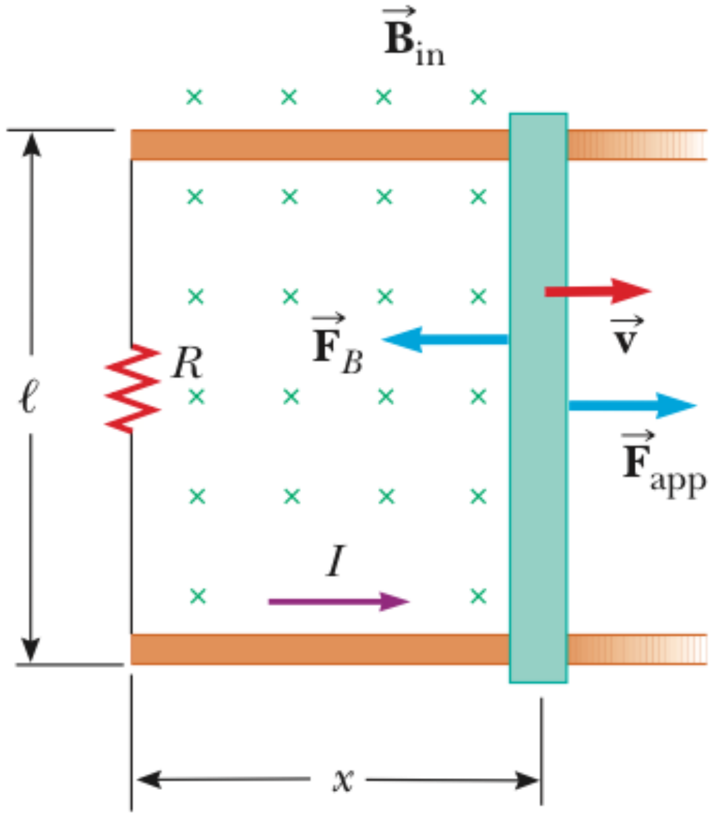
Your camping buddy has an idea for a light to go inside your tent. He happens to have a powerful (and heavy!) horseshoe magnet that he bought at a surplus store. This magnet creates $B = 0.15$ T field between two pole tips $10\ \mathrm{cm}$ apart. His idea is to build a hand-cranked generator shown in Figure. He thinks you can make enough current to fully light a $R = 1.0\ \Omega$ lightbulb rated at $4.0\mathrm{W}$. That's not super bright, but it should be plenty of light for routine activities in the tent.

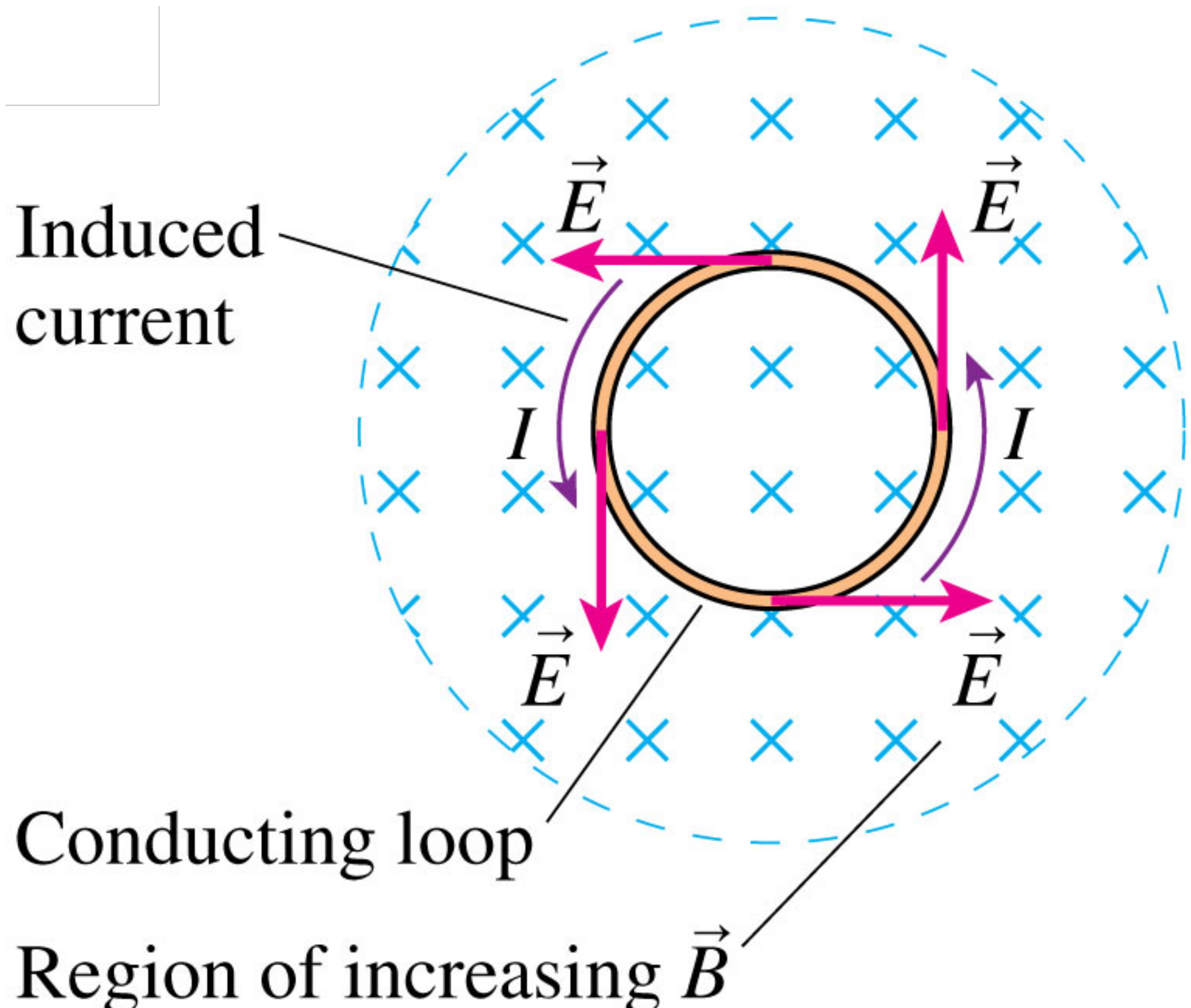
With what frequency will you have to turn the crank for the maximum current to fully light the bulb?

Homework style problem



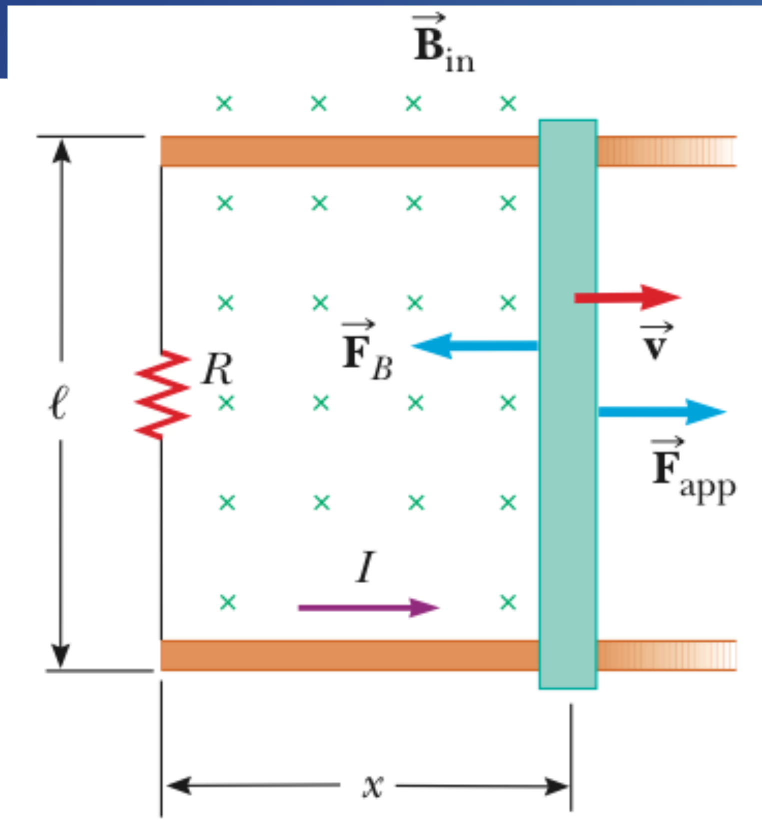
Induced Field

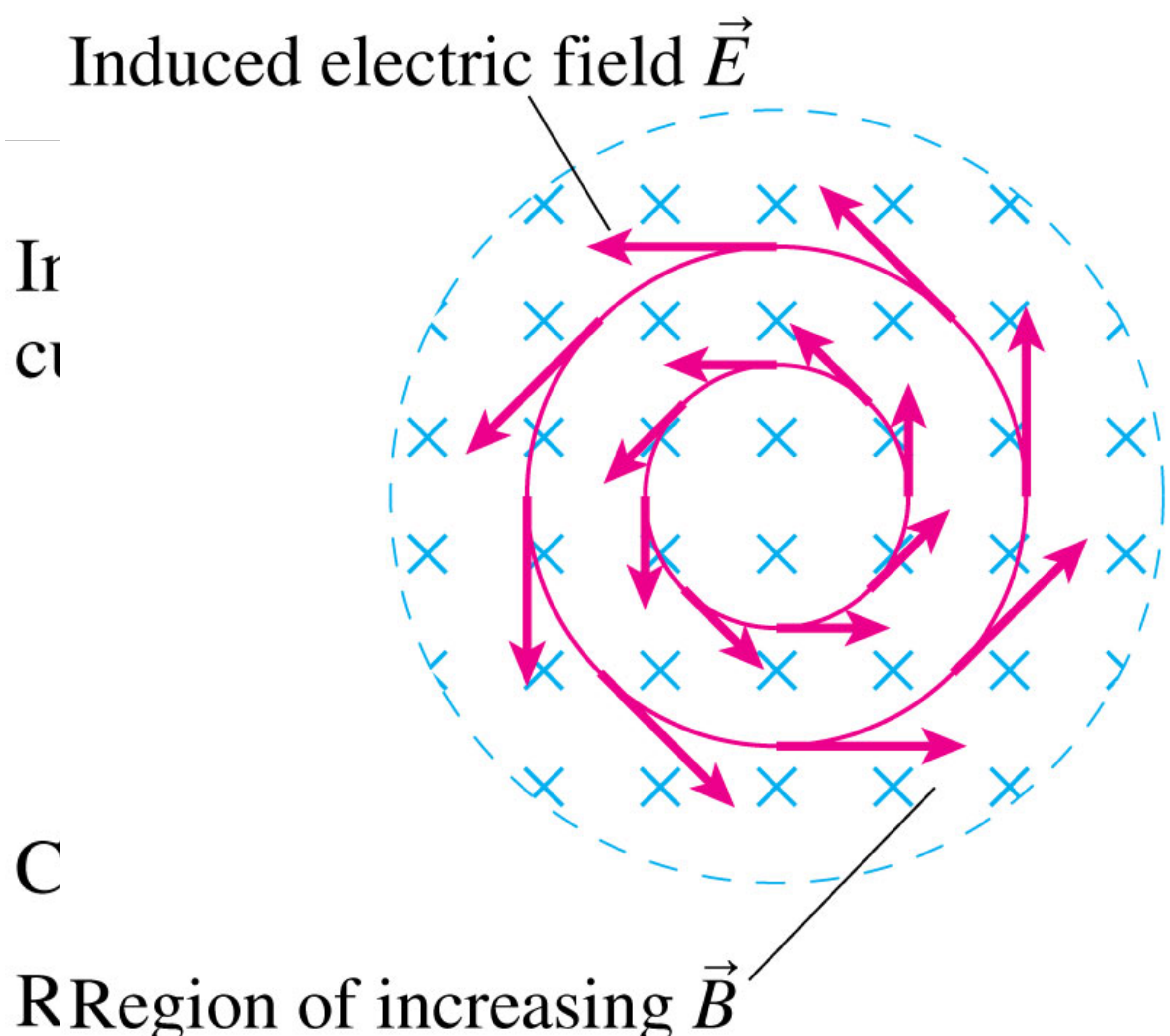




This is not the electric field that we are used to. It's a new kind of field called an "induced" electric field

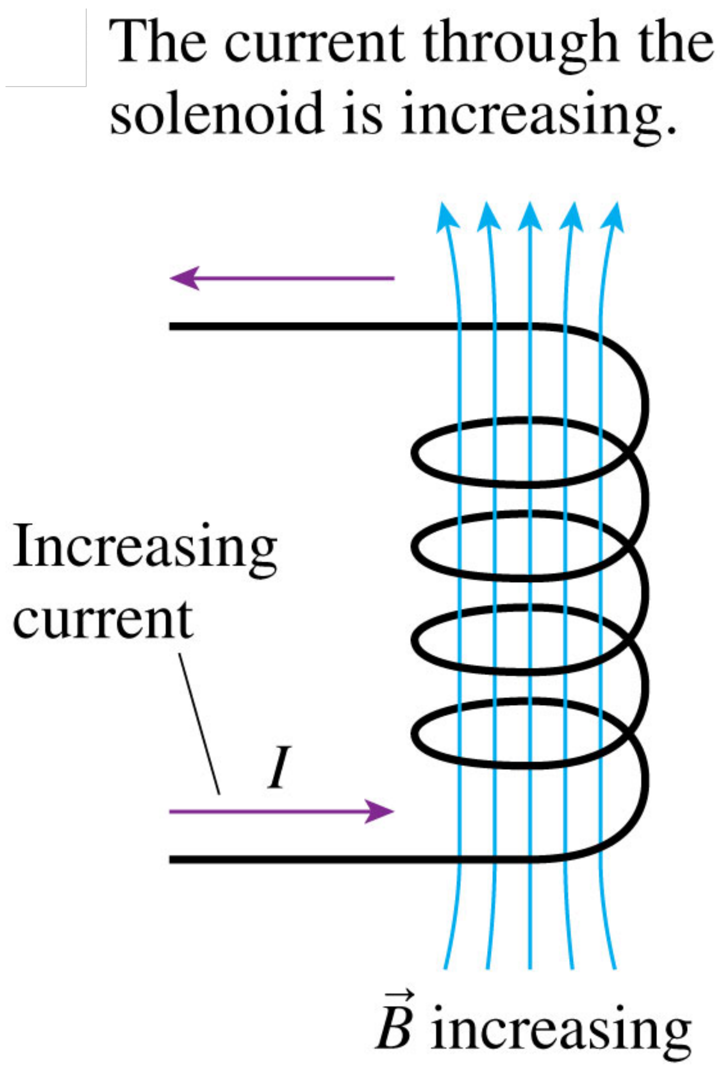
Induced Field





This is not the electric field that we are used to. It's a new kind of field called an "induced" electric field

The field is there whether there is a conductive loop present or not.



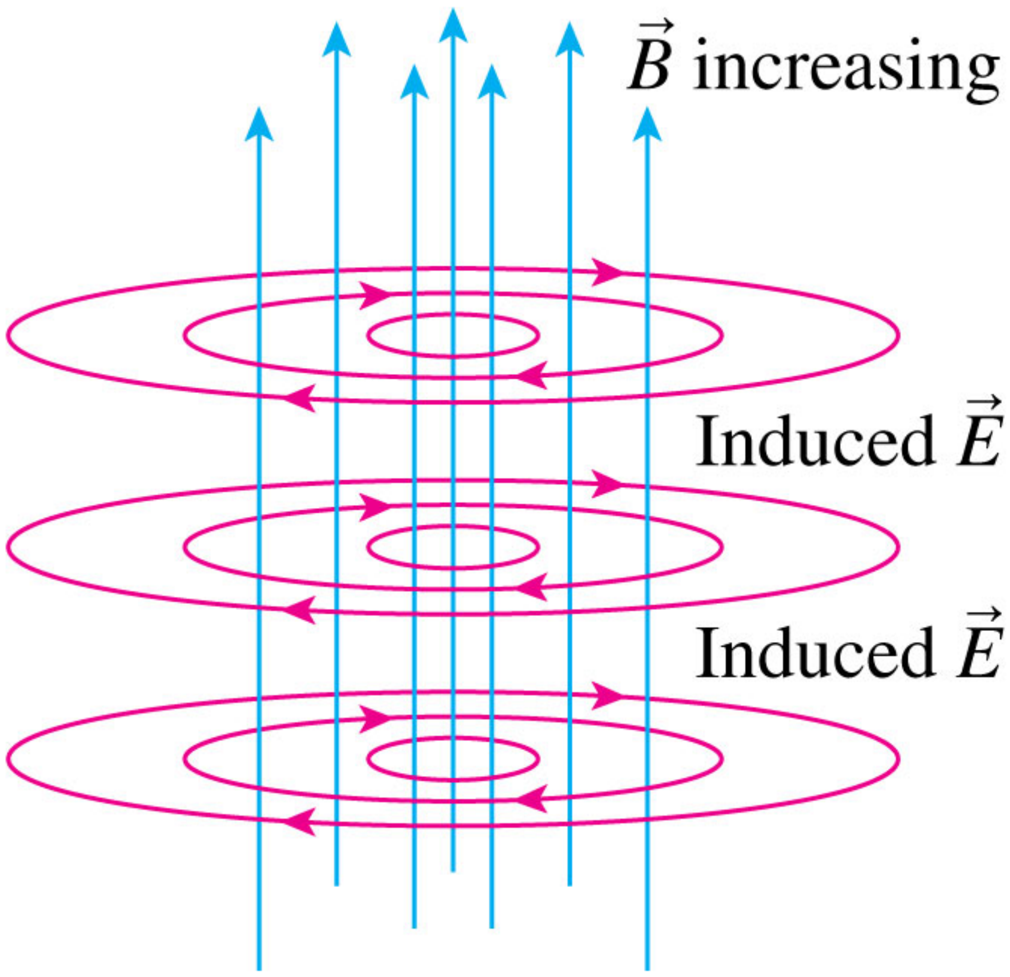
$$\mathcal{E} = \left|\frac{d\Phi}{dt}\right|$$

Convince yourself that the expression below is the same as the expression above for this situation. Then convince your neighbor.

$$\oint \vec{E} \cdot d\vec{s} = A\left|\frac{dB}{dt}\right|$$

Once again: The induced field is there whether the solenoid is present or not.

The induced electric field circulates around the magnetic field lines.



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Convince yourself that the expression below is the same as the expression above for this situation. Then convince your neighbor.

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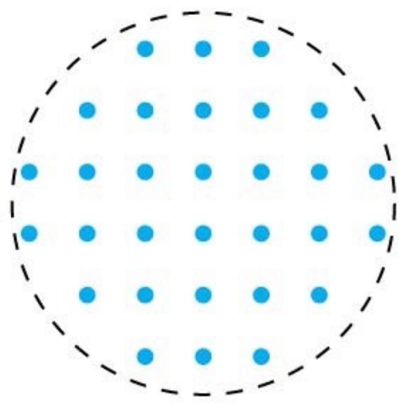
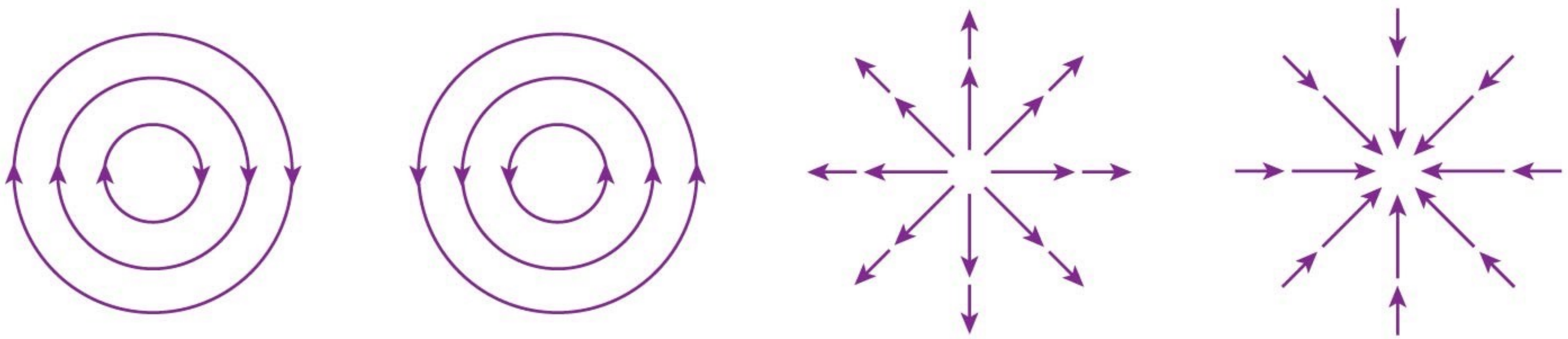
Question #42

The magnetic field is decreasing.
Which is the induced electric field?

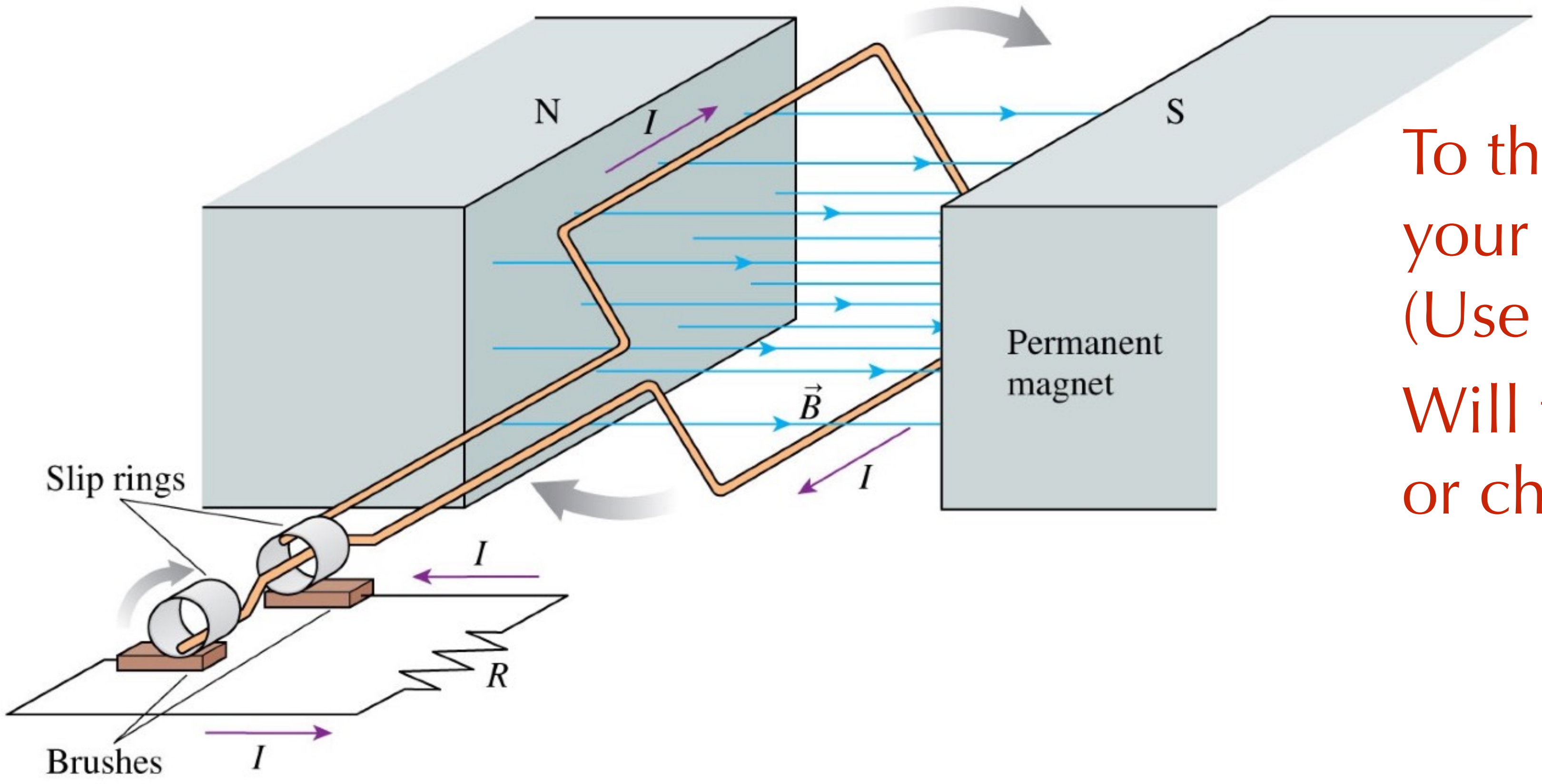




C A B D

E. There's no induced field in this case.

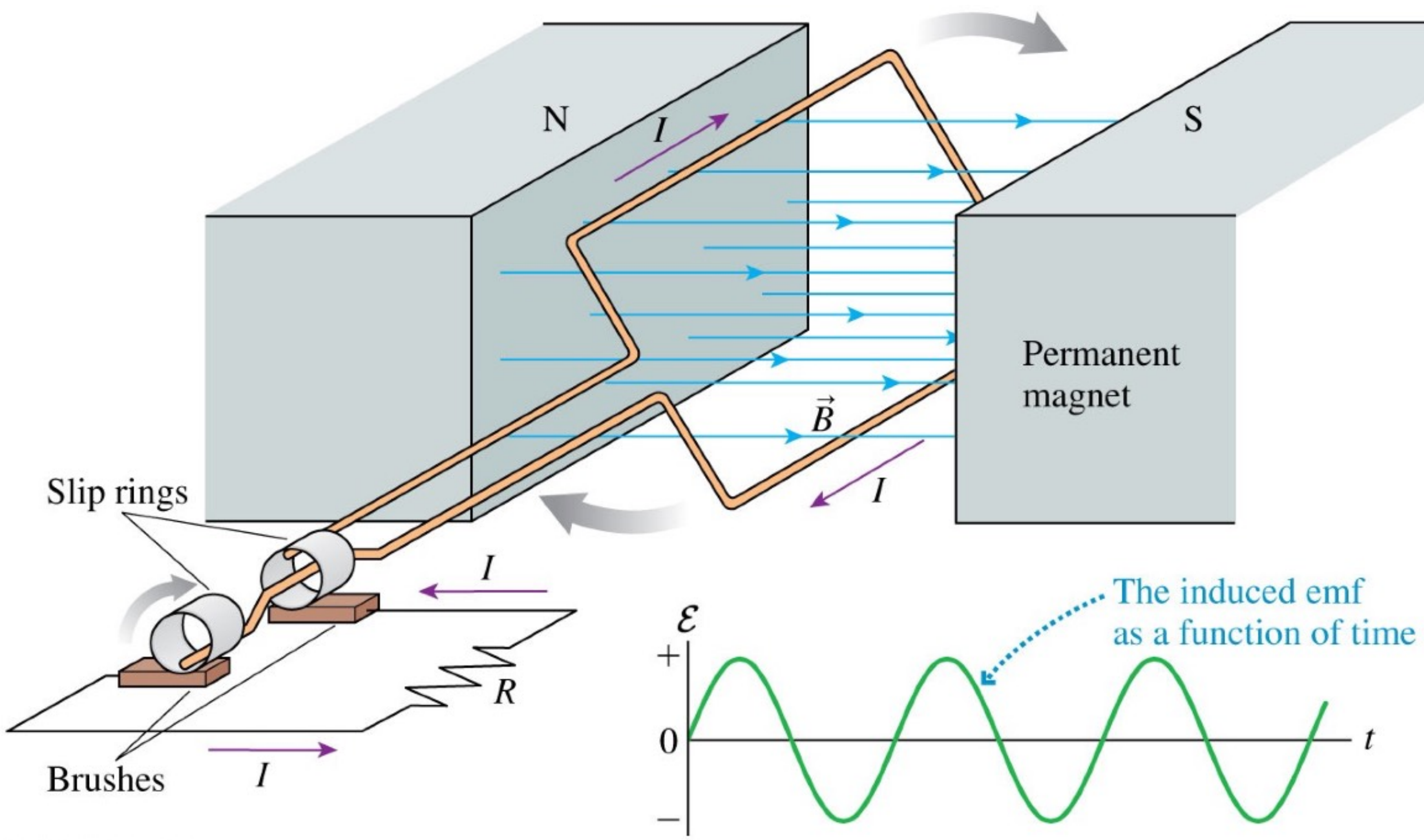
Generator



To the best of your ability, describe to your neighbor how a generator works (Use Faraday's law and Lenz's law).

Will the current in the wire be constant or changing?

Generator



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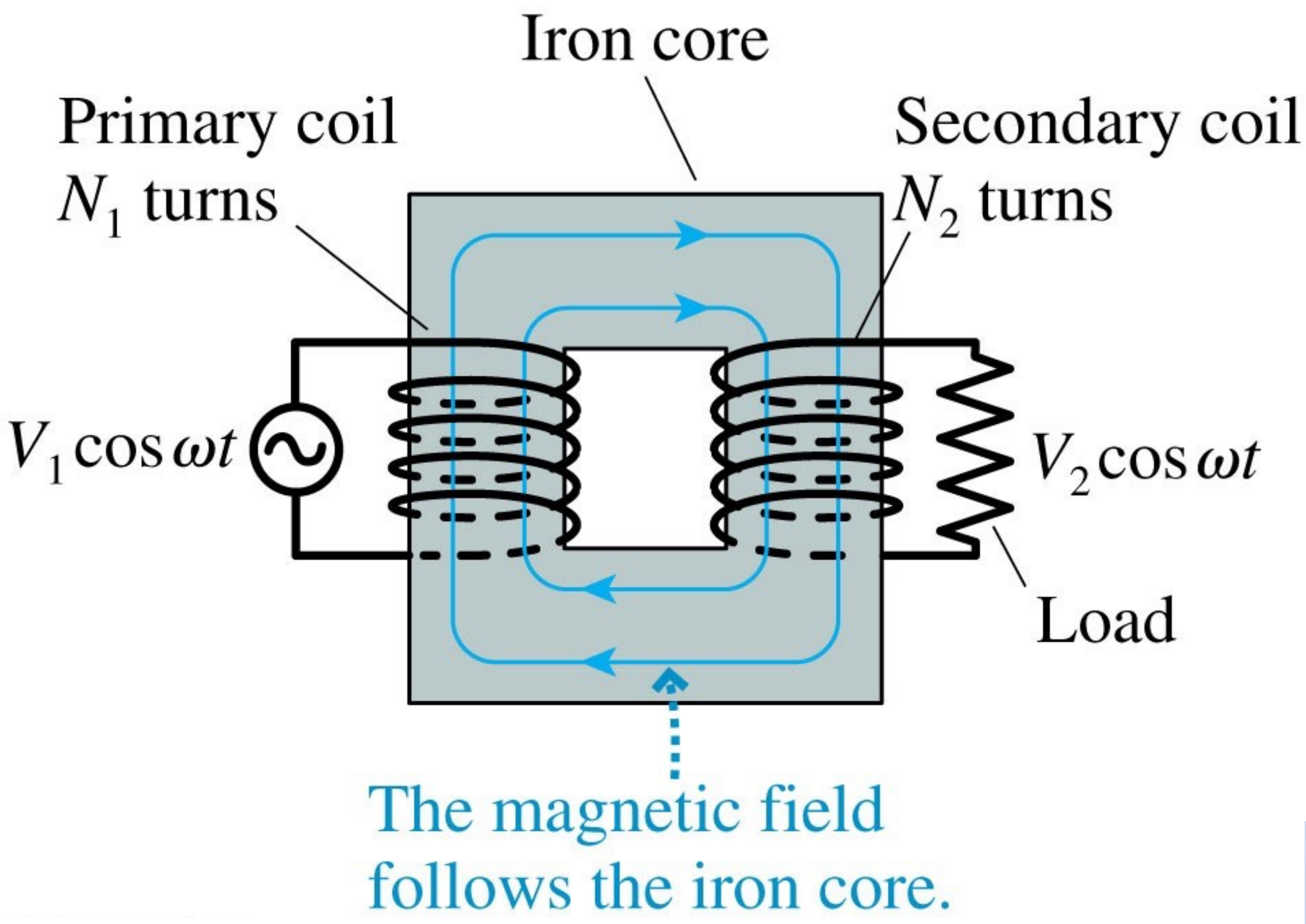
Will the current in the wire be constant or changing?

$$\mathcal{E}_{\text{coil}} = -N\frac{d\Phi_{\text{m}}}{dt} = -ABN\frac{d}{dt}(\cos\omega t) = \omega ABN \sin\omega t$$

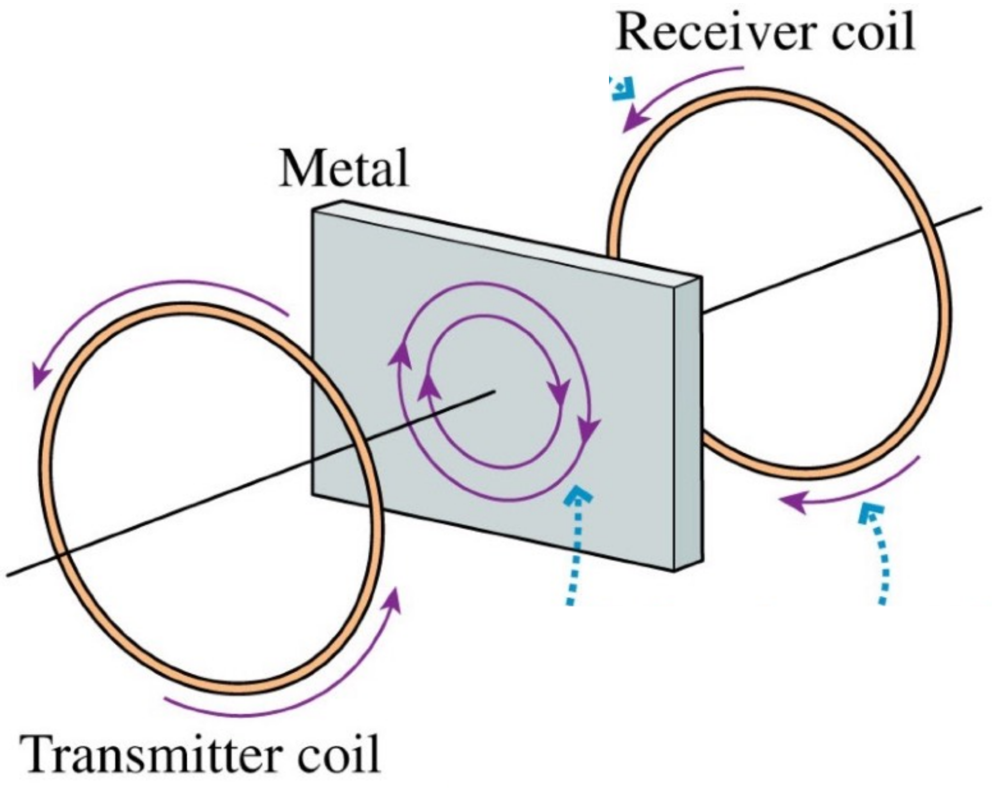


$$\frac{\Phi_2}{N_2} = \frac{\Phi_1}{N_1}$$

$$\Phi_2 = \Phi_1 \frac{N_2}{N_1}$$

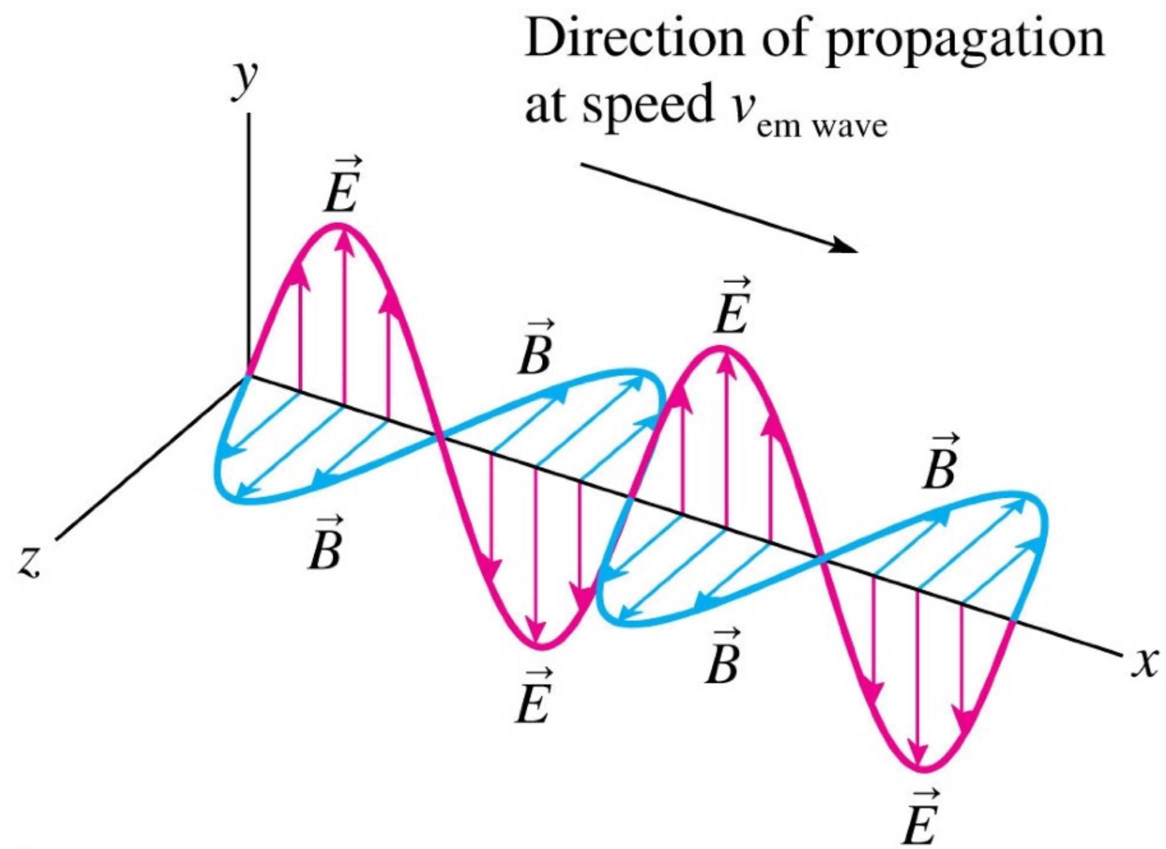
To the best of your ability, describe to your neighbor how a transformer works.

$$V_2 = \frac{N_2}{N_1} V_1$$



To the best of your ability, describe to your neighbor how a metal detector works.

E-M waves



$$v_{\text{em wave}} = \frac{1}{\sqrt{\epsilon_0 \mu_0}}$$

Inductors

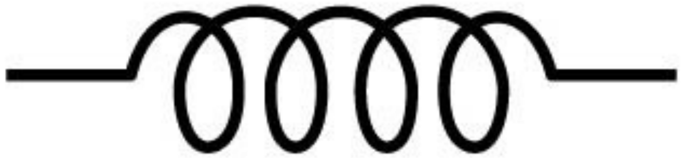
a. Capacitors store energy in the form of an electric field.
b. Resistors dissipate thermal energy.
c. Inductors store energy in the form of a magnetic field.

Inductance

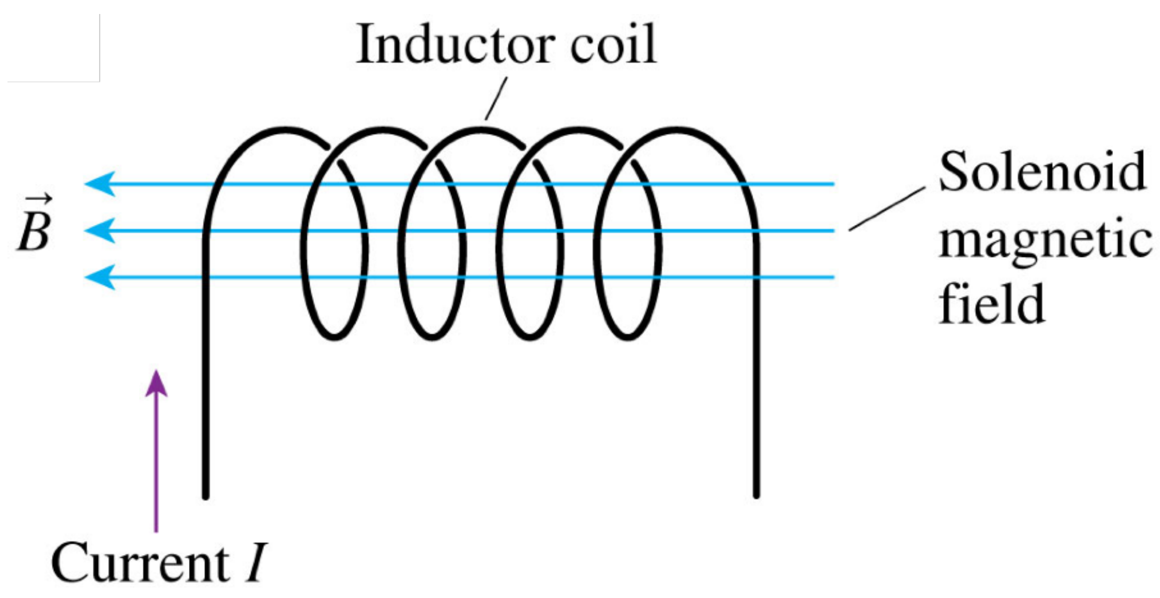
$$L_{\text{solenoid}} = \frac{\Phi_{\text{m}}}{I} = \frac{\mu_0 N^2 A}{l}$$

- The SI unit of inductance is the henry, defined as:

  1 henry = 1 H = 1 Wb/A = 1 T m²/A



Inductors



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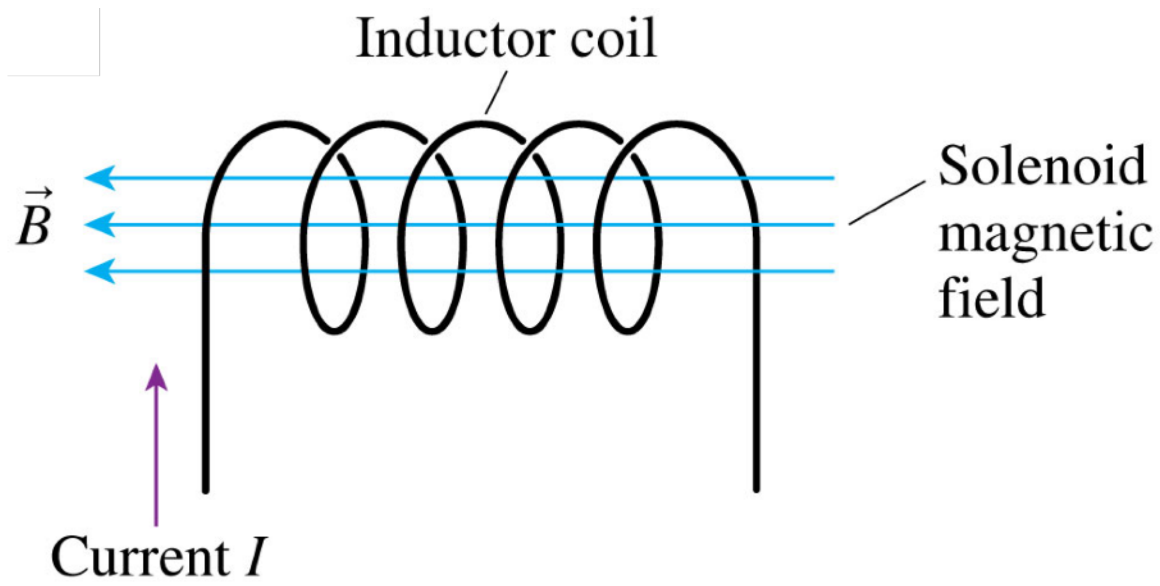
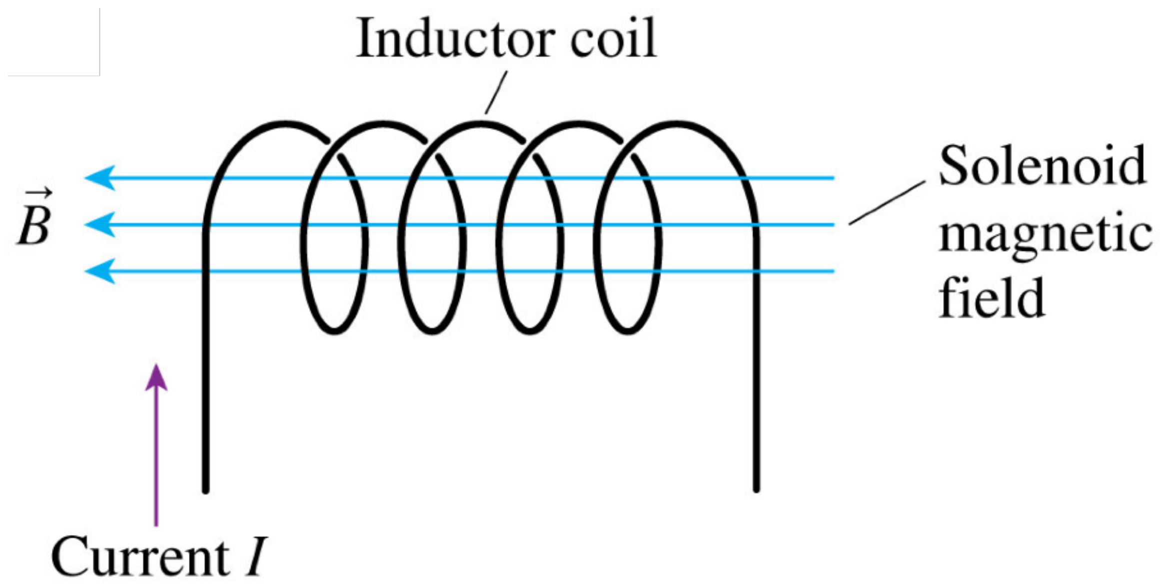
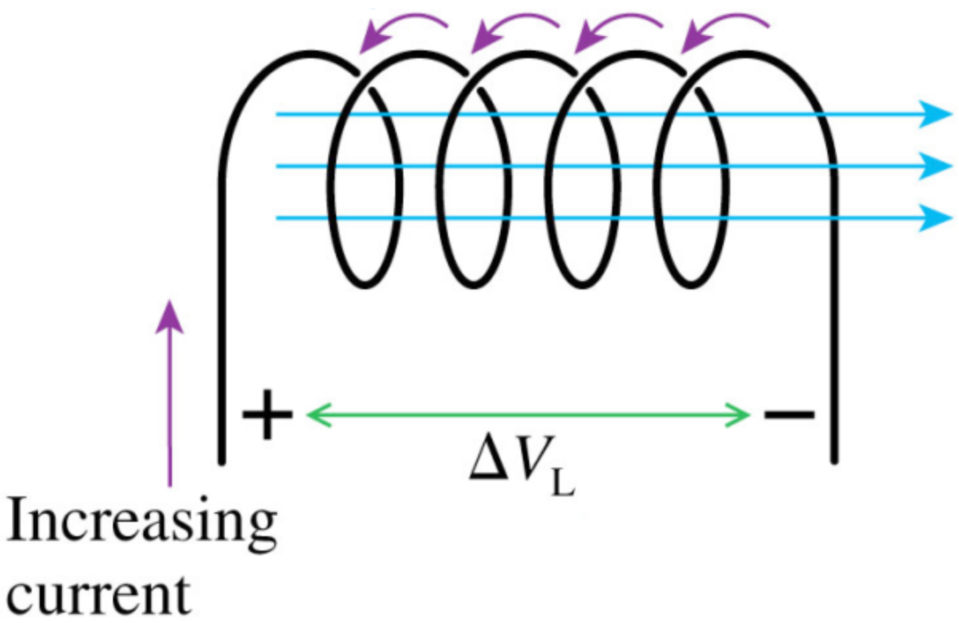


What if I steadily increase the current? What will happen?

Inductors





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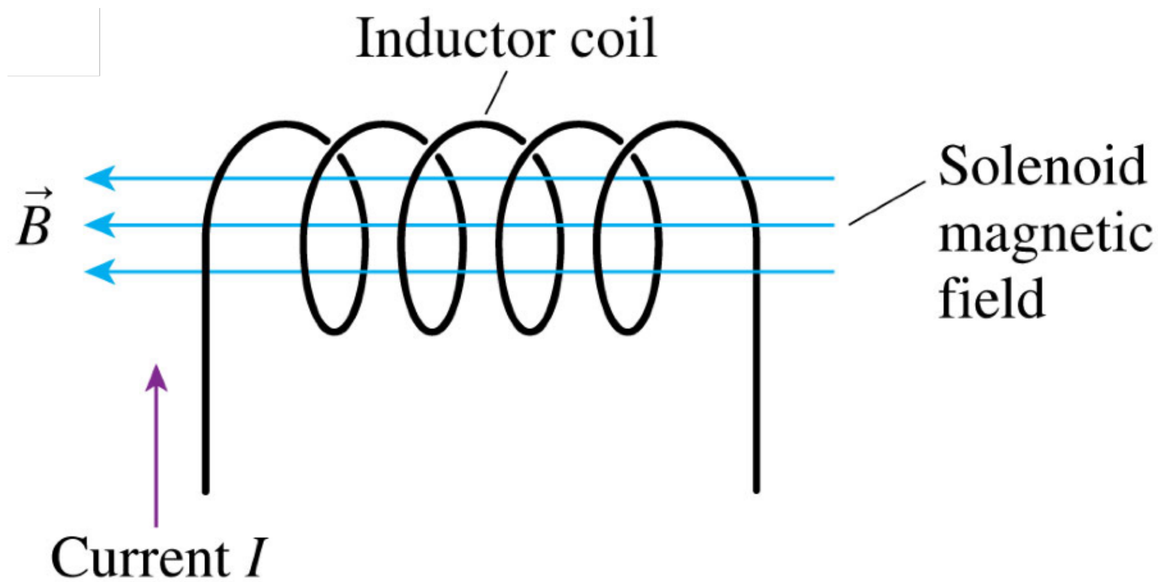
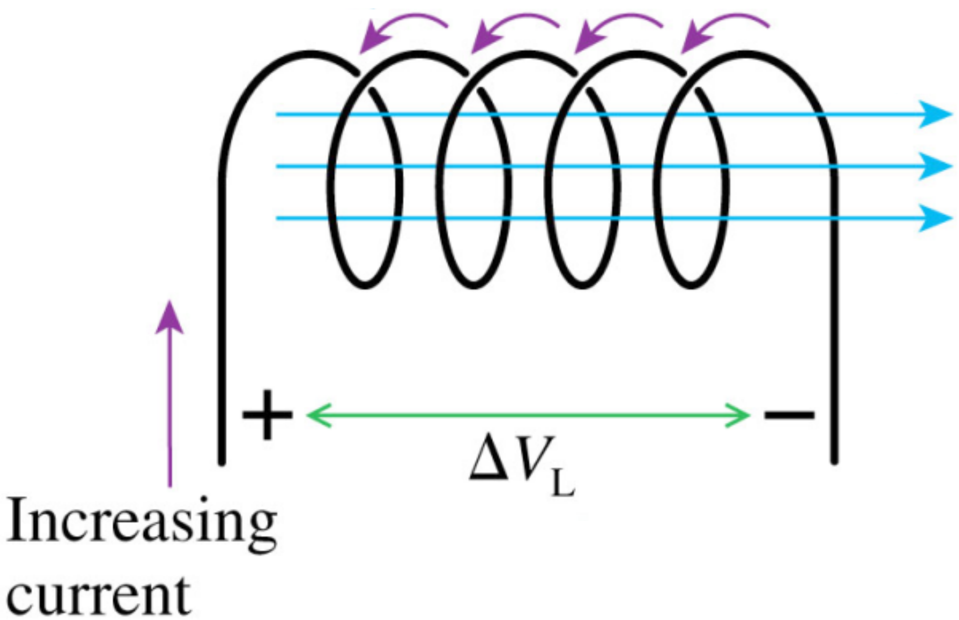
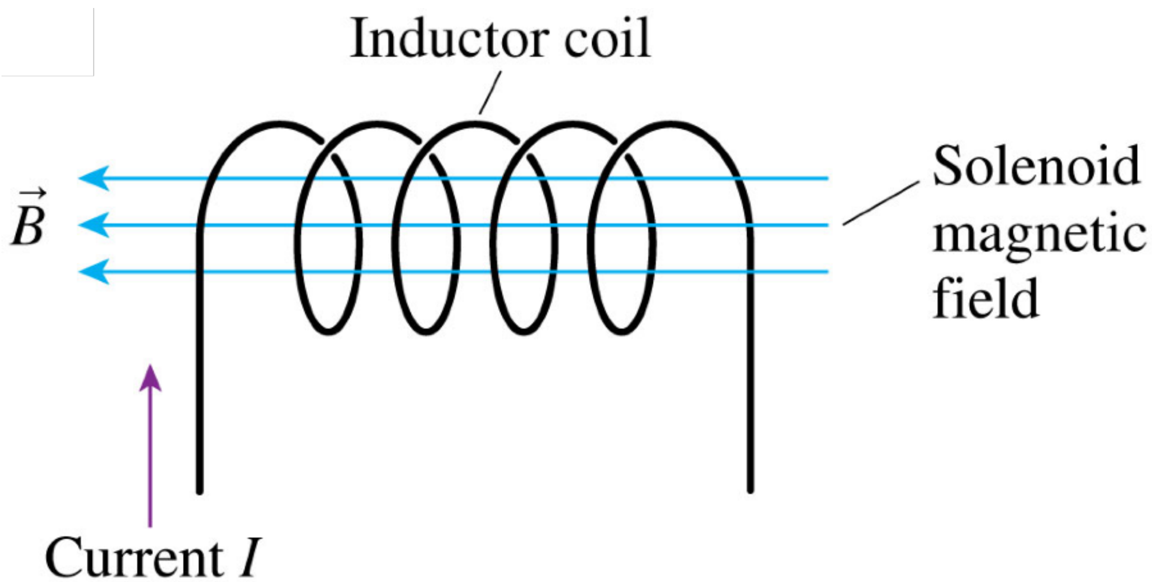
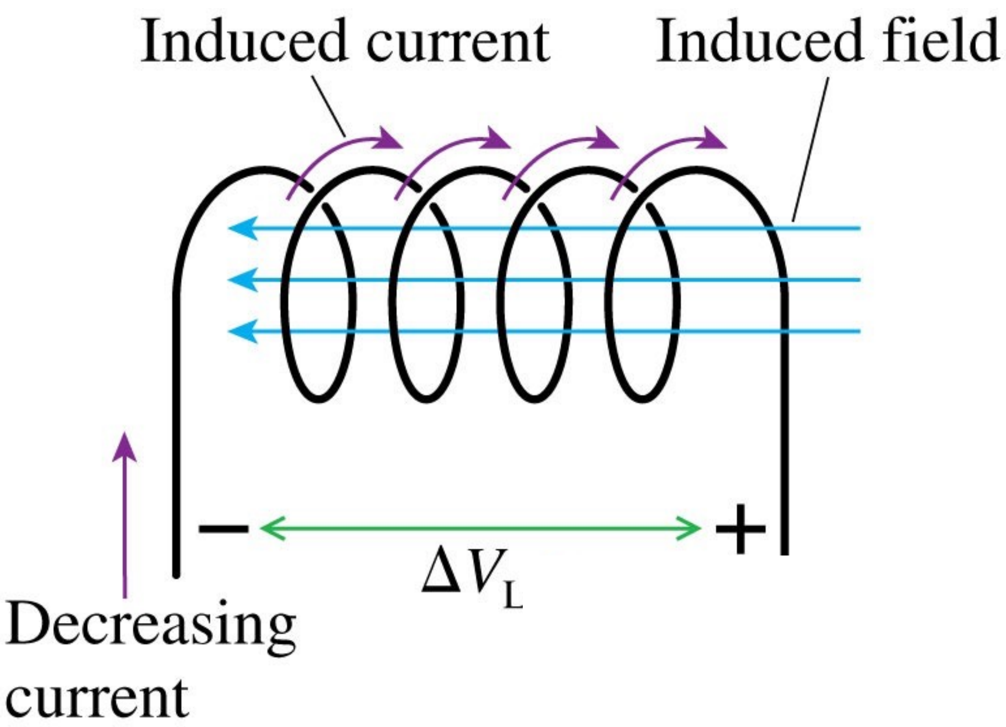




What if I steadily decrease the current? What will happen?

Inductors





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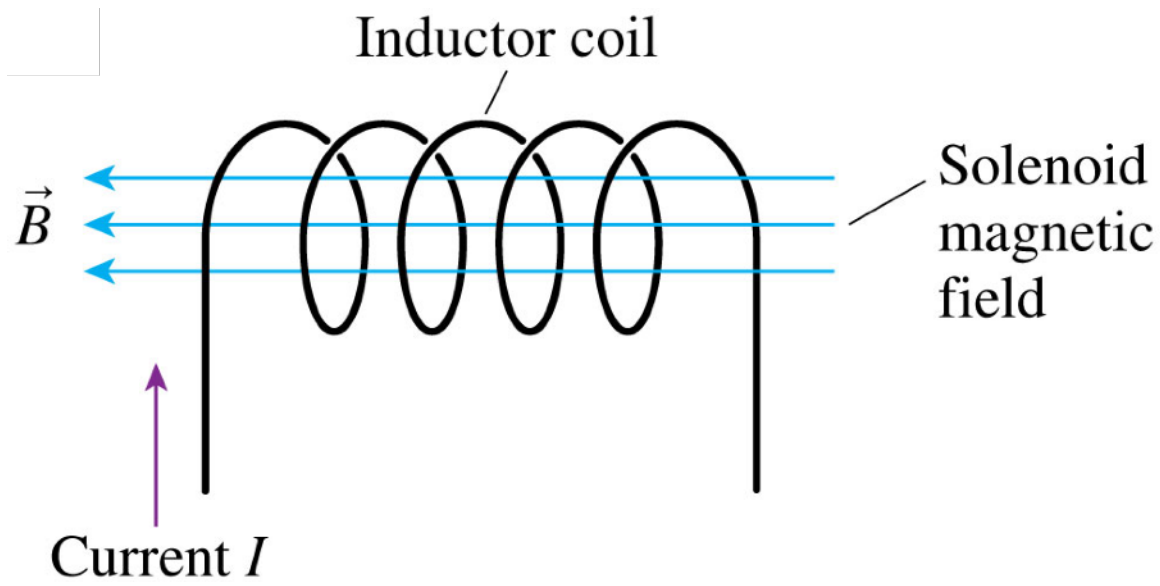
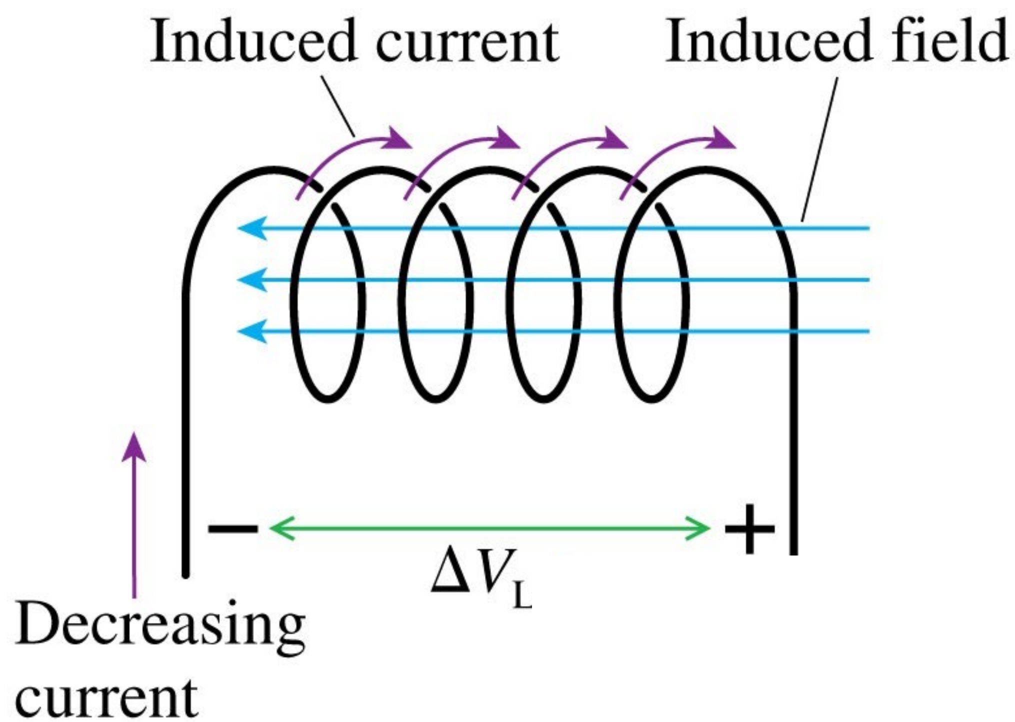
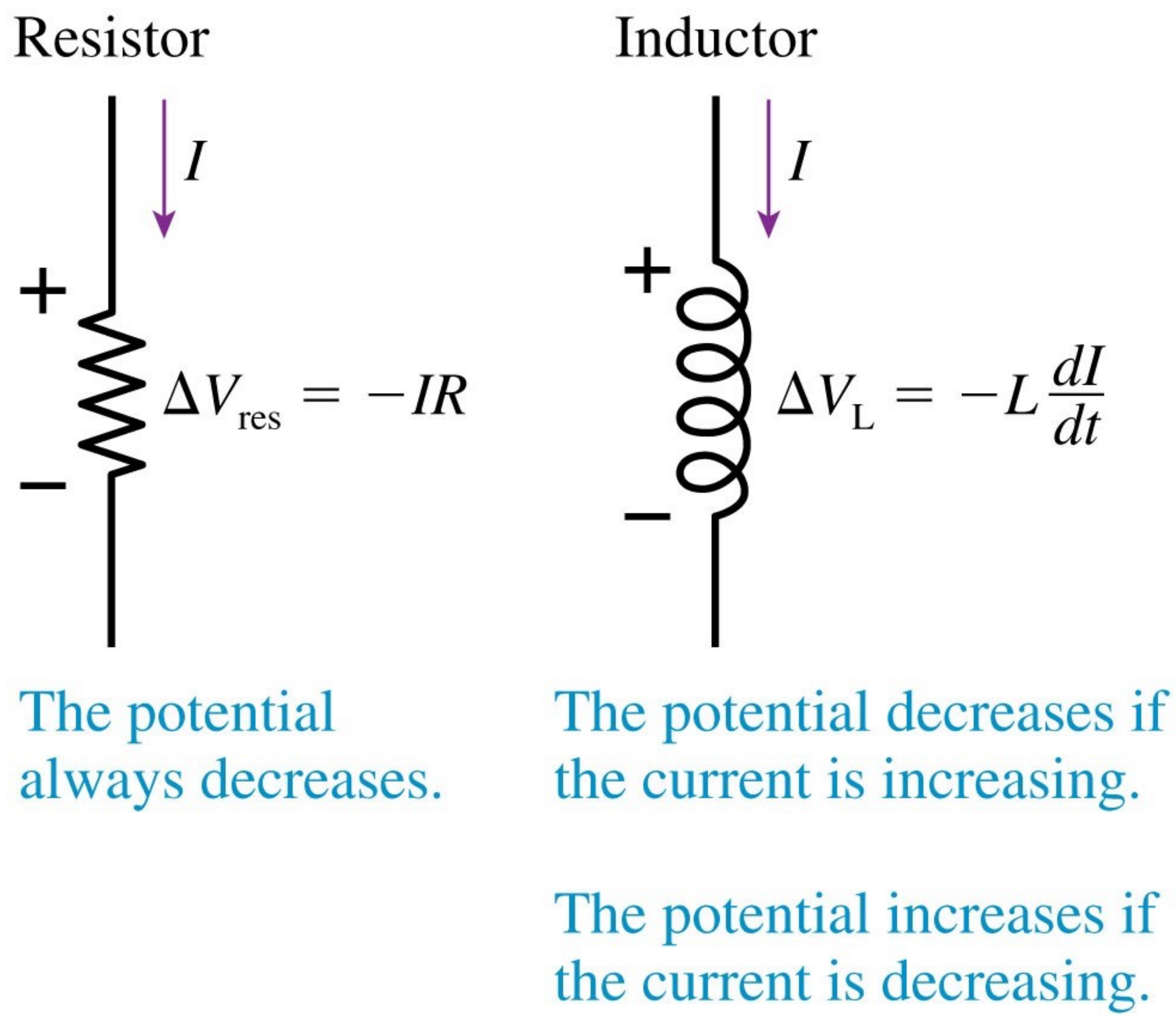




What if I steadily decrease the current? What will happen?

$$\Delta V_L = -L\frac{dI}{dt}$$


Resistor
Inductor
I
I
+
−
+
−
$\Delta V_{\mathrm{res}} = -IR$
$\Delta V_{\mathrm{L}} = -L\frac{dI}{dt}$
The potential always decreases.
The potential decreases if the current is increasing.
The potential increases if the current is decreasing.

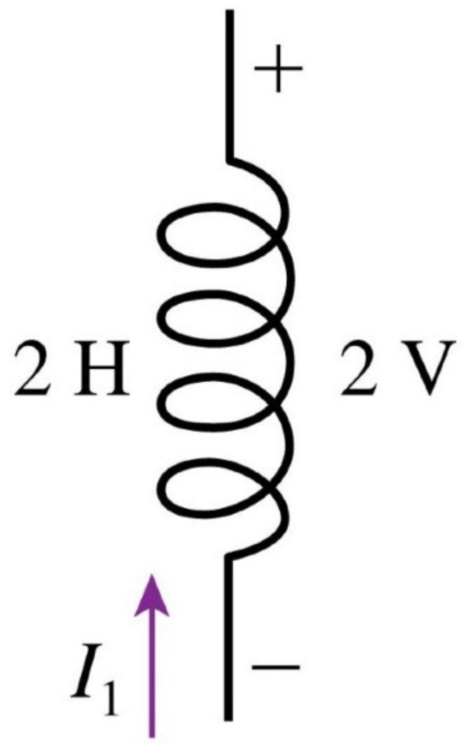
Which current is changing more rapidly?

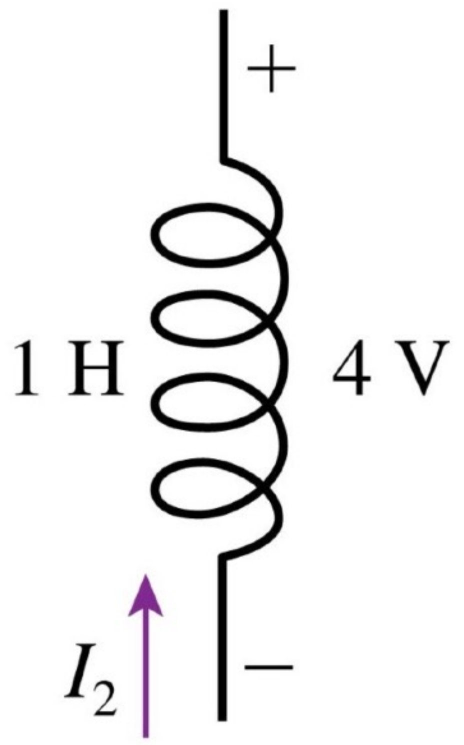
A. Current I_1.

B. Current I_2.

C. They are changing at the same rate.

D. Not enough information to tell.

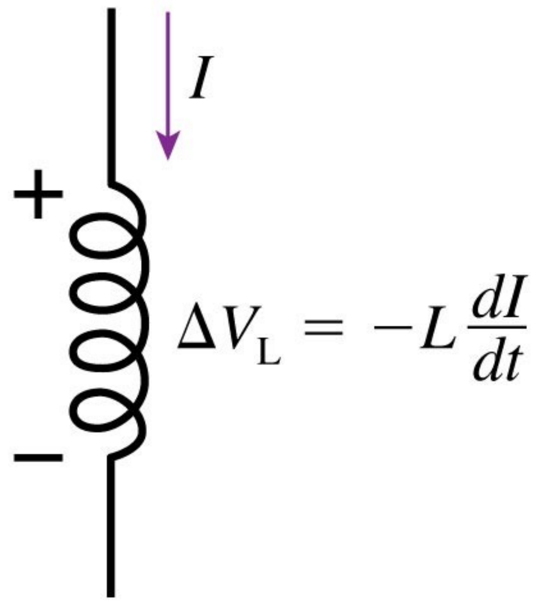




$$P = \frac{dU}{dt} = I\Delta V$$

Substitute in what we just learned for voltage across an inductor

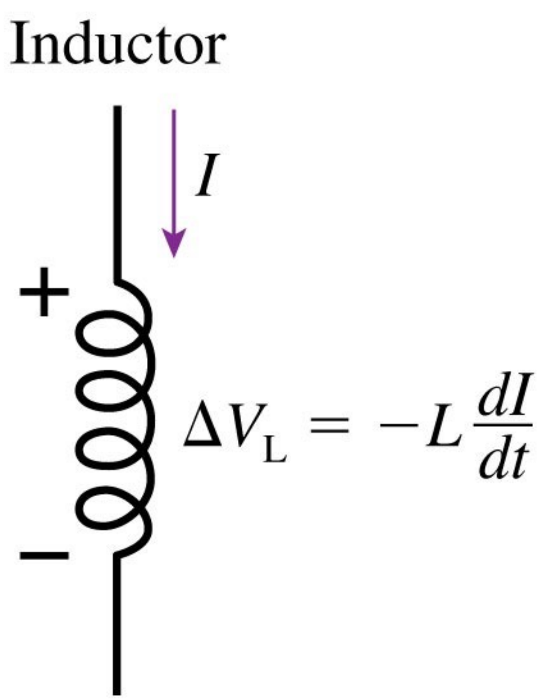
Inductor



$$\frac{dU_L}{dt} =$$

$$P = \frac{dU}{dt} = I\Delta V$$

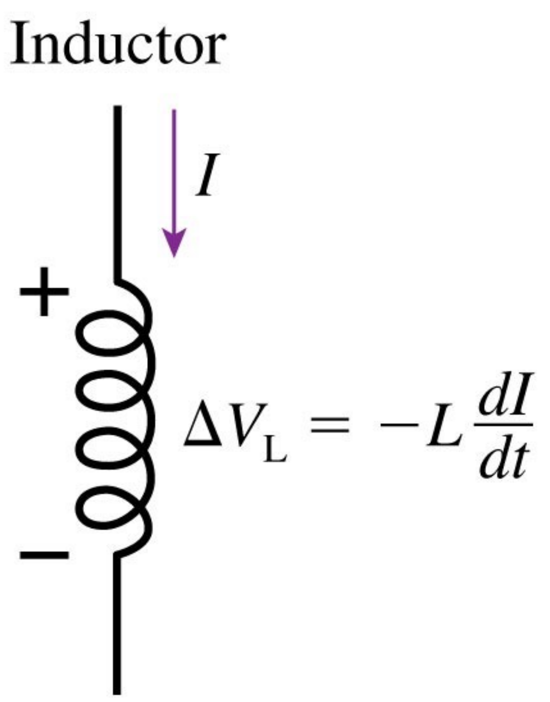
Substitute in what we just learned for voltage across an inductor



$$\frac{dU_L}{dt} = +LI\frac{dI}{dt}$$

$$P = \frac{dU}{dt} = I\Delta V$$

Substitute in what we just learned for voltage across an inductor



$$\frac{dU_L}{dt} = +LI\frac{dI}{dt}$$

Integrate both sides to find the energy stored in an inductor.

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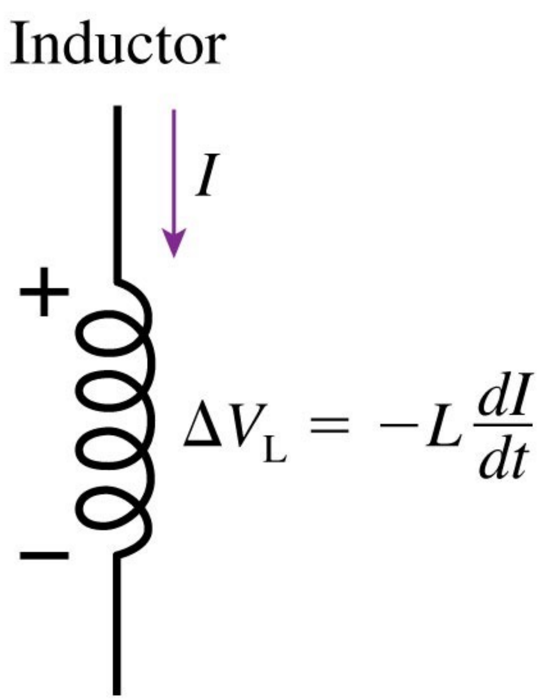

$$\frac{dU_L}{dt} = +LI\frac{dI}{dt}$$

Integrate both sides to find the energy stored in an inductor.

$$U_L = L\int_0^I I\,dI = \frac{1}{2}LI^2$$