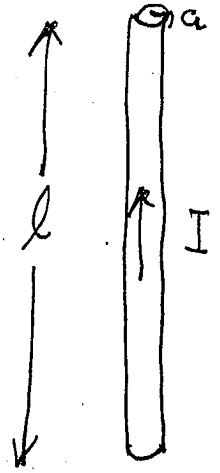
# Lecture # 31
# Review Problems

# Insight into Poynting's Flux

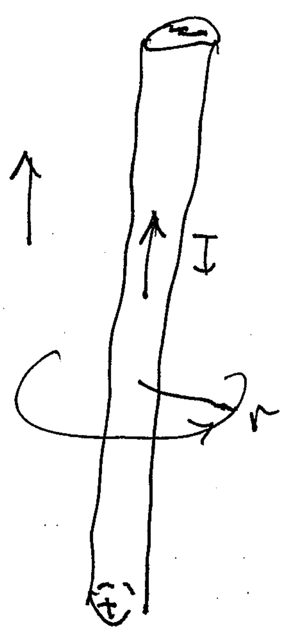



wire radius a, length $\ell$, carries a current I, Resistance is R

Power, P, converted into heat

$$P = I^2 R$$

Poynting Flux gives same result




Voltage Drop = $V = IR$

$$V = E\ell$$

$$E = \frac{IR}{\ell}$$

$$2\pi r B = \mu_0 I$$

at $r = a$

$$B(a) = \frac{\mu_0 I}{2\pi a}$$

$\vec{S} \equiv \frac{\vec{E} \times \vec{B}}{\mu_0}$ is into wire: Gives "wave" interpretation of dissipation

$$\oint \vec{S} \cdot d\vec{A} = \int \frac{\vec{E} \times \vec{B} \cdot d\vec{A}}{\mu_0} = \frac{EB}{\mu_0} 2\pi a \ell = \frac{1}{\mu_0} \frac{IR}{\ell} \cdot \frac{\mu_0 I}{2\pi a} 2\pi a \ell = I^2 R!$$

# Checkup 30.1

Two protons are moving in the same uniform magnetic field. The orbital radius of the first proton is 10 cm, and the orbital radius of the second is 20 cm. Which proton has the larger speed? Which has the larger orbital frequency?

a. ✓ First, first
b. First, second
c. Second, first
d. Second, second
e. Second, both same

$1^{st}$ 10 cm $= r_{L_1}$

$2^{nd}$ 20 cm $\equiv r_{L_2}$

$ma = vBe$

$m\frac{v^2}{R} = vBe$ ; $R = \frac{mv}{eB}$

$\omega = \frac{v}{R} = \frac{eB}{m}$

# Checkup 30.3

A coil in the x–z plane carries a current in the direction shown in the figure below, and is in a region of uniform magnetic field with direction in the x-y plane as indicated. The direction of the torque is:

a. **-I**

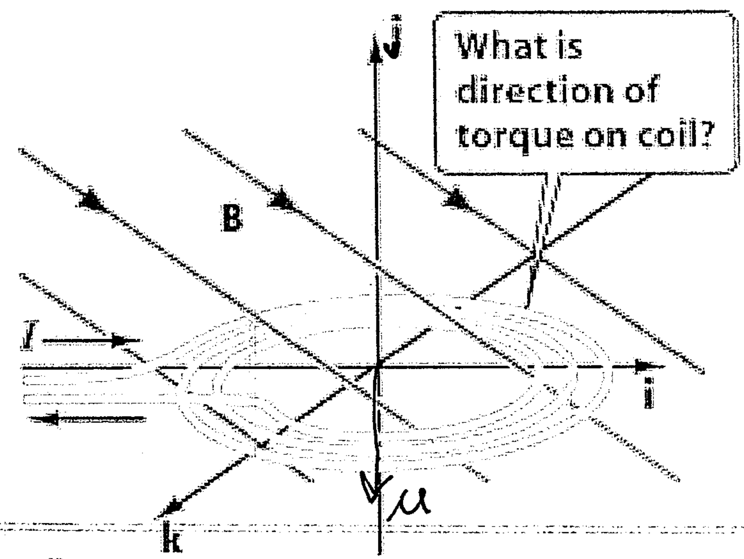
b. **j**

c. **-j**

d. **k**

e. **-k**

$\vec{\tau} = \vec{\mu} \times \vec{B}$




$\mu(-\hat{j}) \times B_x \hat{x}$

$\mu B \; k$

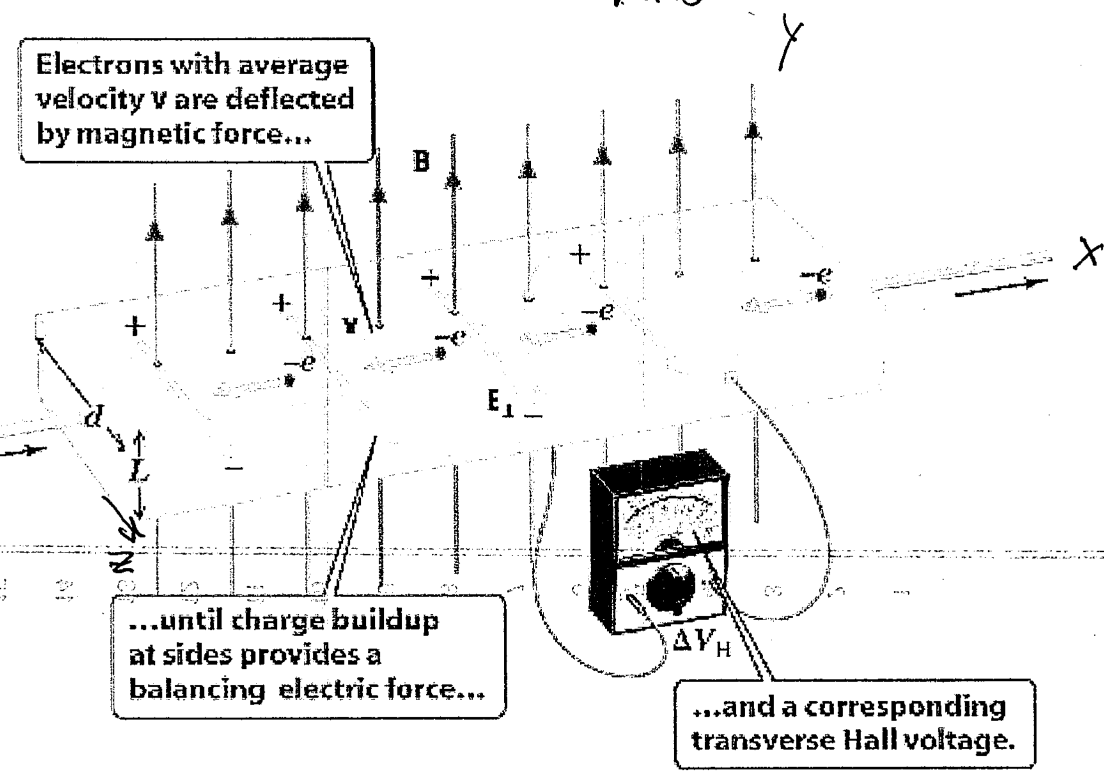

Physics for Engineers and Scientists

# Checkup 30.5

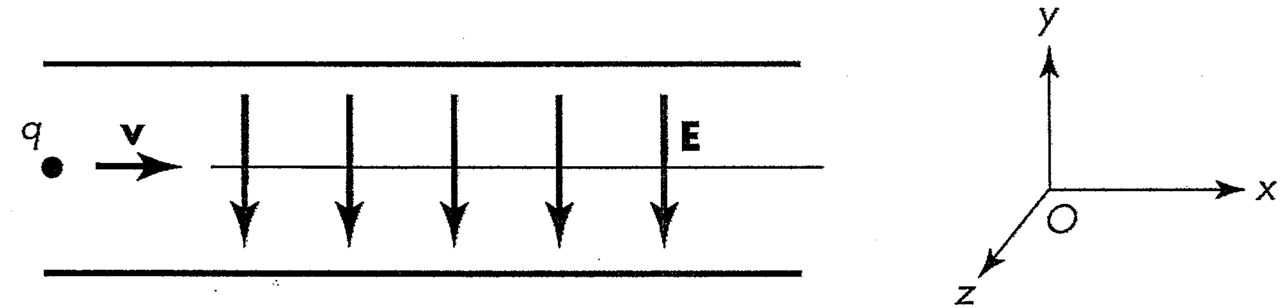
The Hall effect geometry of the figure below shows the case for negative charge carriers. For the current and magnetic field directions shown, consider instead positive charge carriers. Which vectors would reverse direction?

a. **v** only
b. $\mathbf{E}_\perp$ only
c. Both **v** and $\mathbf{E}_\perp$
d. Neither **v** nor $\mathbf{E}_\perp$

**v** is velocity of the flowing charge carriers



# PhysiQuiz 30-3




A charged particle with a positive charge $q$ is moving with velocity **v** along the positive $x$ direction, as shown. **E** is pointing along the negative $y$ direction. Find the direction of the magnetic field **B** such that $q$ may pass through the **E** field region without any deflection:

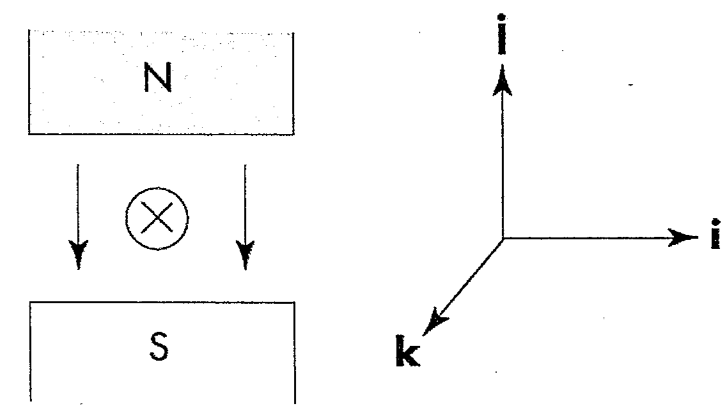
$\underset{\sim}{V} = \vec{E} \times \vec{B}$

| | A | B | C | D |
|---|---|---|---|---|
| **B** | ← | → | In | Out |

**Hint:** **F** = q**v** × **B**.

**Extra:** Find the magnitude of **B** in the case described. What would be the direction of **B** if $q$ were negative?

# PhysiQuiz 30-4




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

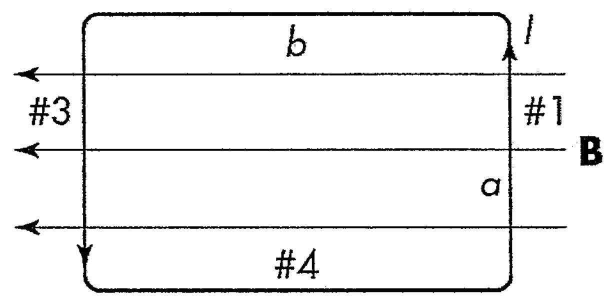
$= +k \times -\hat{j} = -i$

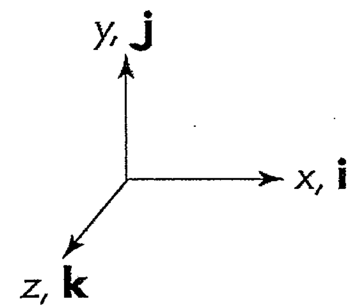
The diagram shows an electric current passing between a gap between two bar magnets. **B** is downward (−**j**) and the current *I* is into the page (−**k**). Determine the direction of force on the current:

| | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Dir of magnetic force | +**i** | −**i** | +**j** | −**j** |

**Hint:** Use $\Delta\mathbf{F} = I\,\Delta\mathbf{L} \times \mathbf{B}$.

# PhysiQuiz 30-7




$\mu = I A \hat{n}$

$\hat{n} = \hat{k}$

$\tau = \vec{\mu} \times \vec{B}$

$\hat{k} \times (-i)$

$= -j$

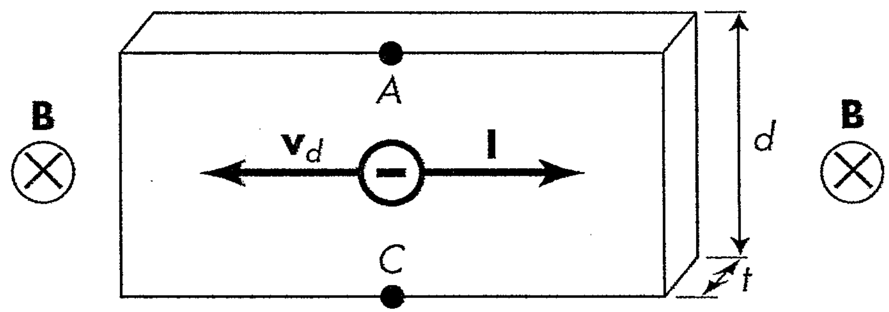
The diagram shows a magnetic field passing along a current-carrying loop. The current **I** is counterclockwise. The loop area is $a \times b$. And **B** is along −**i**. Find the direction of the torque $\tau$ on the loop due to **B**:

| | A | B | C | D |
|---|---|---|---|---|
| Direction of $\tau$ | **j** | −**j** | **k** | −**k** |

**Hint:** Use $\mathbf{F} = I\mathbf{L} \times \mathbf{B}$. For the direction of the torque, use the right-hand rule of rotation.

**Extra:** The following sketch is viewed from the bottom along +**j**.

# PhysiQuiz 30-10



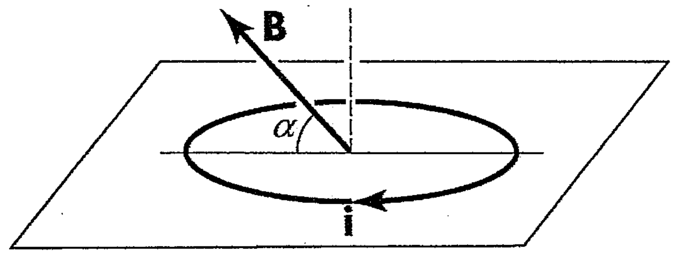

Consider the setup shown of a Hall experiment. The cross section of the metal strip (the shaded area) is given by $t \times d$. **B** is into the paper. Compare the potentials at $A$ and $C$:

| A | B |
|---|---|
| $V_A > V_C$ | $V_A < V_C$ |

**Hint:** Use $\mathbf{F} = q\mathbf{v} \times \mathbf{B}$. There should be excess charges at the upper and lower edges. This leads to a potential difference.

**Extra:** Show that the magnitude of Hall voltage $|V_A - V_C| = v_d B d$. The potential difference here is given by $V = \text{Work}/q = Fd/q$.

# PhysiQuiz 30-8




The diagram here shows a current loop with a magnetic field passing through it. The angle between the **B** field and the perpendicular projection of **B** in the plane of the loop is $\alpha$. Determine the direction of the magnetic moment of the loop $\boldsymbol{\mu}_{loop}$, and the angle between $\boldsymbol{\mu}_{loop}$ and **B**:

| | A | B | C | D |
|---|---|---|---|---|
| Direction of $\boldsymbol{\mu}_{loop}$ | ↓ | ↑ | ↓ | ↑ |
| Angle between $\boldsymbol{\mu}_{loop}$ & **B** | $\frac{\pi}{2} - \alpha$ | $\frac{\pi}{2} - \alpha$ | $\frac{\pi}{2} + \alpha$ | $\frac{\pi}{2} + \alpha$ |

**Hint:** $\boldsymbol{\mu}_{loop} = iA\mathbf{n}$, where **n** is the unit normal vector is defined by the right-hand rule.

**Extra:** Determine the magnetic torque vector.

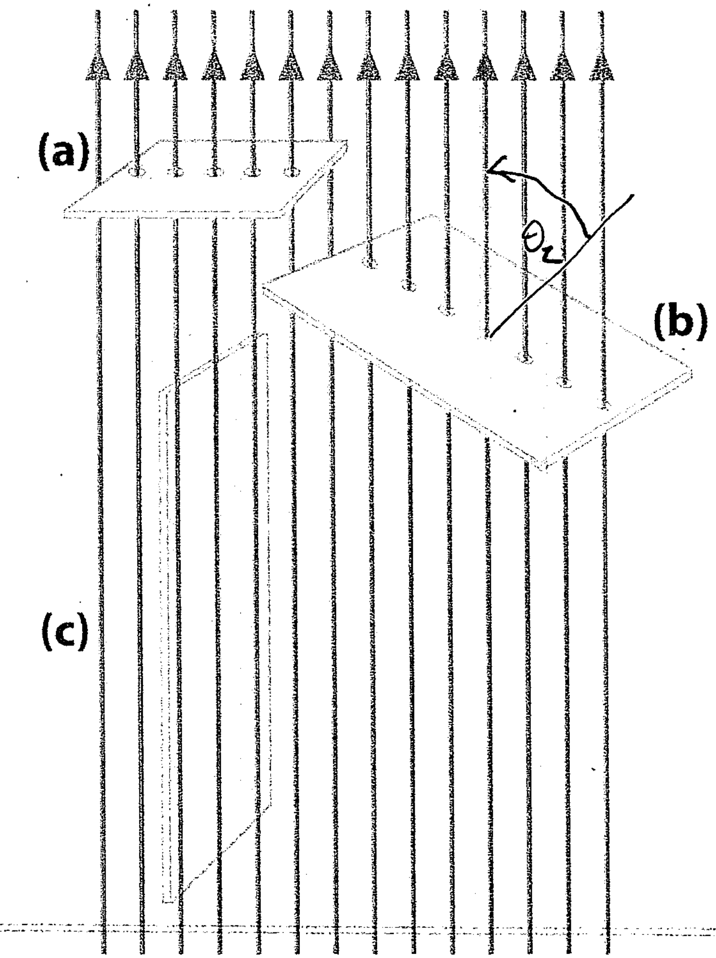
# Checkup 31.2

This figure shows several surfaces in a uniform magnetic field. Which has the largest magnetic flux?

A

B

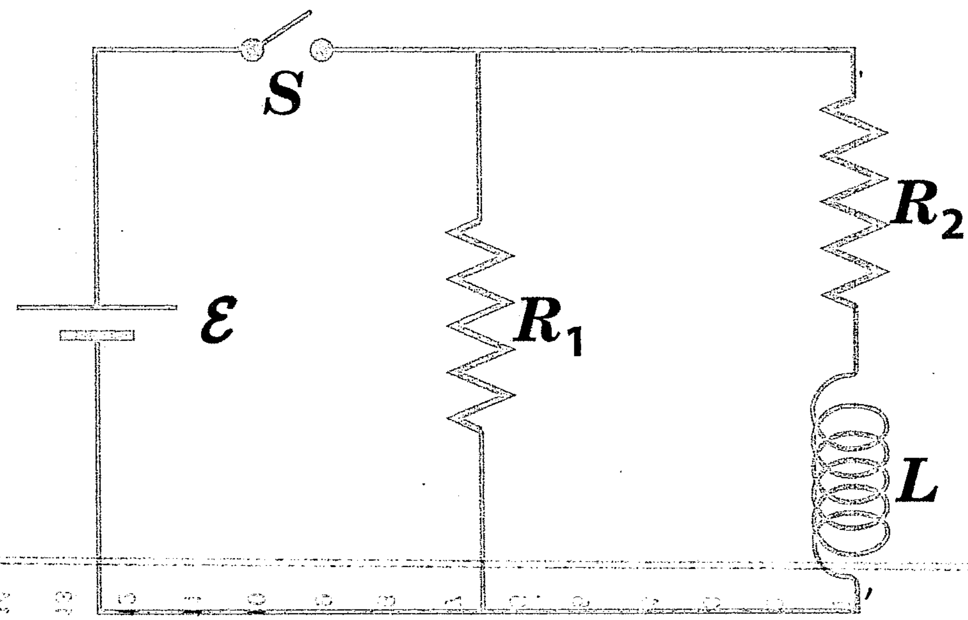
C



# Checkup 31.6

The switch S in the figure below has been open for a long time. At t = 0 it is closed. What is the current through the inductor immediately after closing the switch?

- 0
- $E / R_1$
- $E / R_2$
- $E / (R_1 + R_2)$
- $E (R_1 + R_2) / R_1 R_2$

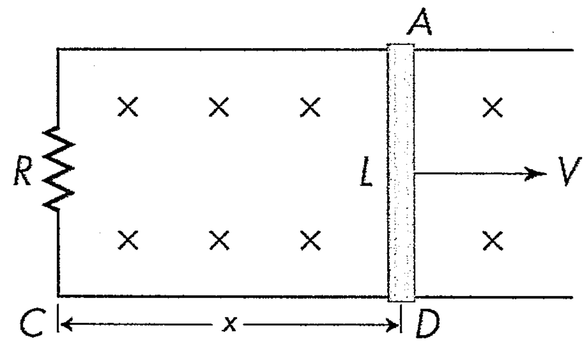






ℰ / R2

# PhysiQuiz 31-1



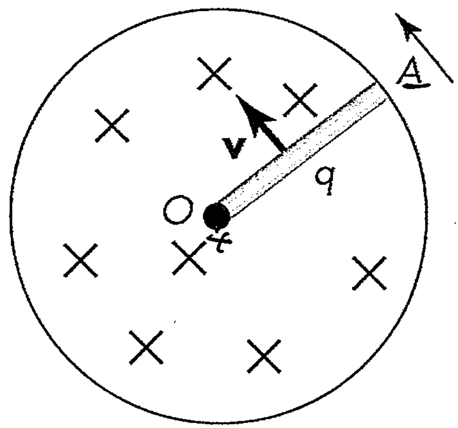

A metal rod *AD* is sliding to the right along the parallel metal railings shown. The resistance connecting the railings is *R*. Also, there is a magnetic field **B** directed into the paper. $L = AD$. Determine the direction of the induced current:

| | A | B | C |
|---|---|---|---|
| Direction of $\mathbf{i}_{ind}$ | Clockwise | 0 | Counterclockwise |

**Hint:** Lenz's Law states that $B_{ind}$ tends to maintain the original flux.

**Extra**: Based on $\varepsilon_{ind} = -\frac{d\phi}{dt} = -\frac{d}{dt}(BLx)$, $i_{ind} = \frac{\varepsilon_{ind}}{R}$.
Show that $i_{ind} = BvL/R$.

# PhysiQuiz 31-4




Consider a metal bar $OA$, shown rotating in a plane perpendicular to a magnetic field **B**, directed into the page. Which end of the bar has a higher potential?

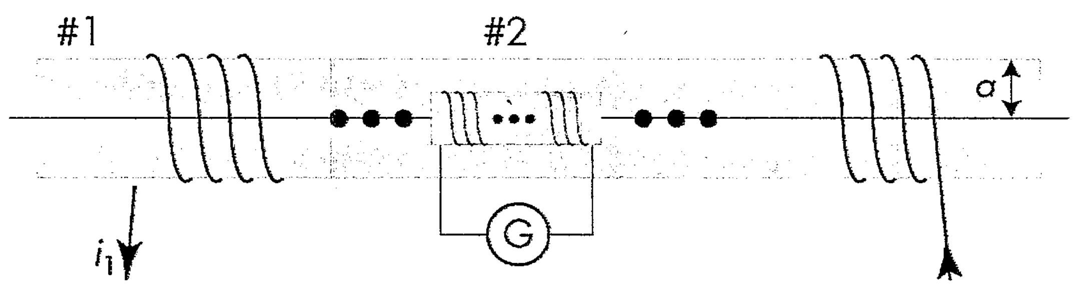
| | A | B | C |
|---|---|---|---|
| $V_O$ versus $V_A$ | $V_O < V_A$ | $V_O = V_A$ | $V_O > V_A$ |

**Hint:** The magnetic force due to **B** asserted on $q$, a positive charge on the rod, is given by $\mathbf{F} = q\mathbf{v} \times \mathbf{B}$. This force "pushes" $q$ from a low-potential point to a higher-potential point.

**Extra:** Show that $|V_O - V_A|$ the magnitude of the potential difference is $\omega BR^2/2$, where $R = OA$ and $\omega$ is the angular frequency of rotation.

***Hint:*** When $q$ is pushed by a displacement $\Delta r$, the corresponding potential difference is given by $\Delta V = F\Delta r/q = qvB\Delta r/q = \omega Br\Delta r$.

# PhysiQuiz 31-6




In the situation shown here, solenoid #2 is placed inside the much larger solenoid #1. Solenoid #1 has $N_1$ turns, radius $a$, and length $d_1$. Solenoid #2 has $N_2$ turns, radius $b$, and length $d_2$. Determine the mutual inductance of the system:

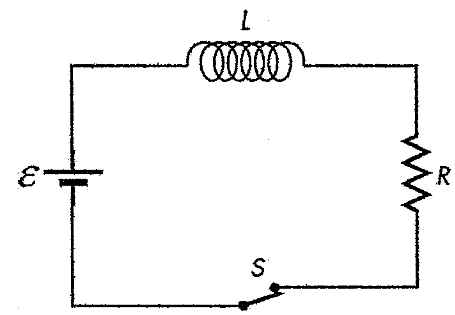
| | |
|---|---|
| A | $\mu_0 N_1 N_2 \pi a^2/d_1$ |
| B | $\mu_0 N_1 N_2 \pi b^2/d_1$ ✓ |
| C | $\mu_0 N_1 N_2 \pi a^2/d_2$ |
| D | $\mu_0 N_1 N_2 \pi b^2/d_2$ |

$\frac{N_2}{d_2} I \mu_0$

$M = \frac{\Phi_{b2}}{I_1} = B_2 N_2 \pi b^2 / I_1 = \frac{\mu_0 I_0 N_1 \pi b^2 N_2}{I_1 d_1}$

**Hint:** $\varepsilon_{2,\text{ind}} = -N_2 \frac{d\phi}{dt} = M_{21} \frac{di_1}{dt}$, where $\phi$ is the magnetic flux at #2 due to $i_1$.

# PhysiQuiz 31-8




For the resistor–inductor circuit shown here, the loop equation is $\mathcal{E} - V_L - iR = 0$, where $V_L = L di/dt$. Find the current and voltage $i$ and $V_L$ at $t = 0_+$, that is immediately after the switch $S$ was closed at $t = 0$:

| | A | B | C | D |
|---|---|---|---|---|
| $i$ | $\mathcal{E}/R$ | 0 | $\mathcal{E}/R$ | 0 |
| $V_L$ | $\mathcal{E}$ | $\mathcal{E}$ | 0 | 0 |

**Hint:** The inductor has an initial flux of zero. Lenz law implies that the inductor has magnetic inertia, meaning it has the tendency to maintain its no flux status. So at $t = 0_+$, we expect the flux through the inductor should still be approximately zero.

**Extra:** Find $i$ at $t \approx \infty$, where the current has reached a steady state in which $di/dt \approx 0$.