Example 30.7 (and more)

If the rectangular loop has a width b and a length c, find the New magnetic force exterted by wire 1 on on the loop.

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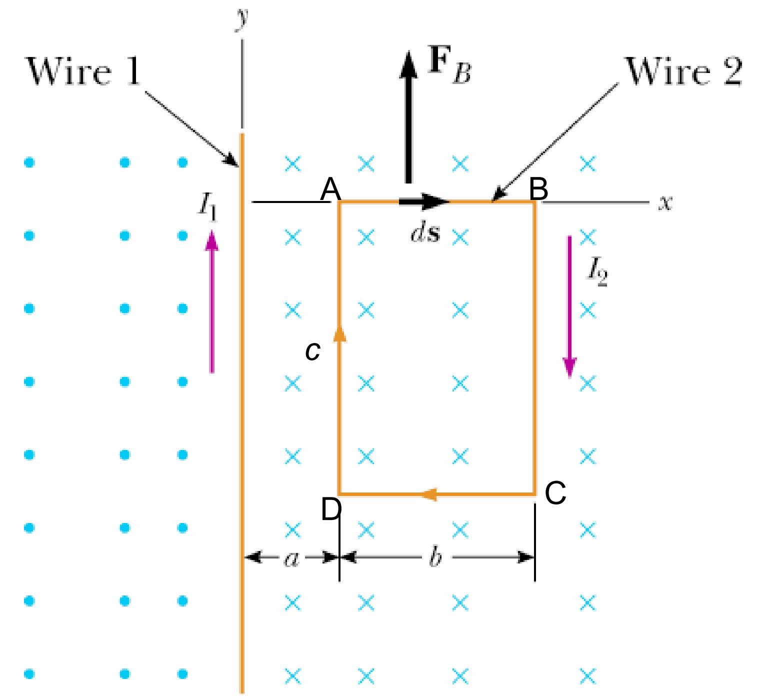
Figure 30.15



Field due to wire 1, at a distance x from wire 1: Into the paper.

$$B = \frac{\mu_0 I_1}{2\pi x}$$

First find the force on each segment of the loop.

- segment AB: Force $\mathbf{F}_{AB}$ is in $+y$ direction

$$d\mathbf{F} = I_2 d\mathbf{s} \times \mathbf{B} \tag{11}$$

$$dF = I_2 \frac{\mu_0 I_1}{2\pi x} dx$$

$$F_{AB} = \frac{\mu_0 I_1 I_2}{2\pi} \int_a^{a+b} \frac{dx}{x}$$

$$F_{AB} = \frac{\mu_0 I_1 I_2}{2\pi} \ln\left(1 + \frac{b}{a}\right)$$

- segment CD: Force $\mathbf{F}_{CD}$ is in $-y$ direction, and has same magnitude as F_{AB}
- segment BC: Two parallel wires with currents in opposite directions (repel each other): $\mathbf{F}_{BC}$ is in $+x$:

$$F_{BC} = \frac{\mu_0 I_1 I_2}{2\pi(a+b)} c$$

- segment DA: Two parallel wires with currents in the same direstion (attract each other): $\mathbf{F}_{DA}$ is in $-x$:

$$F_{DA} = \frac{\mu_0 I_1 I_2}{2\pi a} c$$

- $\mathbf{F}_{AB}$ and $\mathbf{F}_{CD}$ cancell each other; but $\mathbf{F}_{DA} > \mathbf{F}_{BC}$. So there is a net force on the loop in $-y$ direction:

$$F = F_{DA} - F_{BC} \tag{12}$$

$$= \frac{\mu_0 I_1 I_2}{2\pi a} c - \frac{\mu_0 I_1 I_2}{2\pi(a+b)} c$$

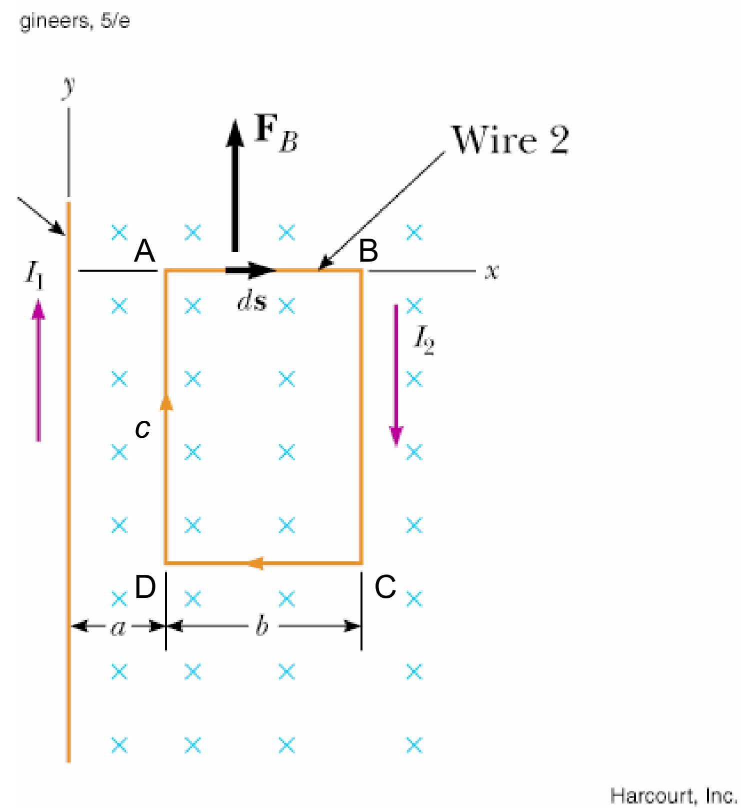


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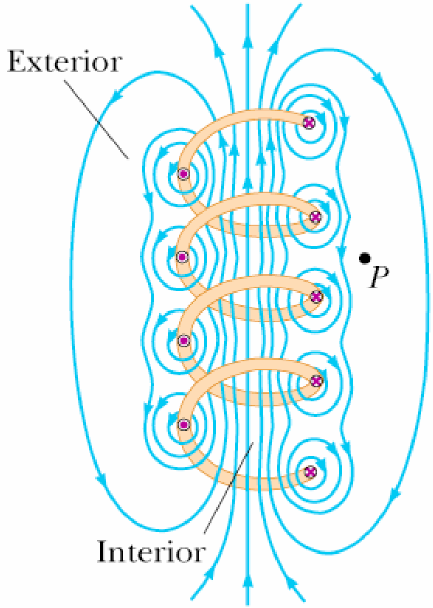
Figure 30.16



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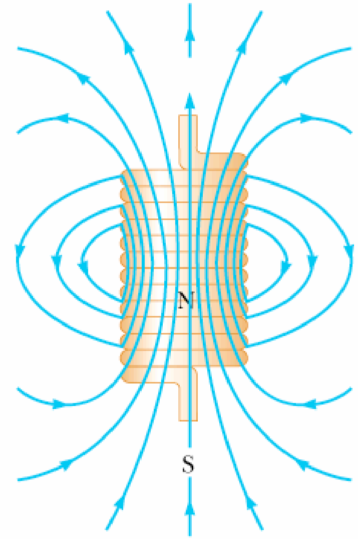

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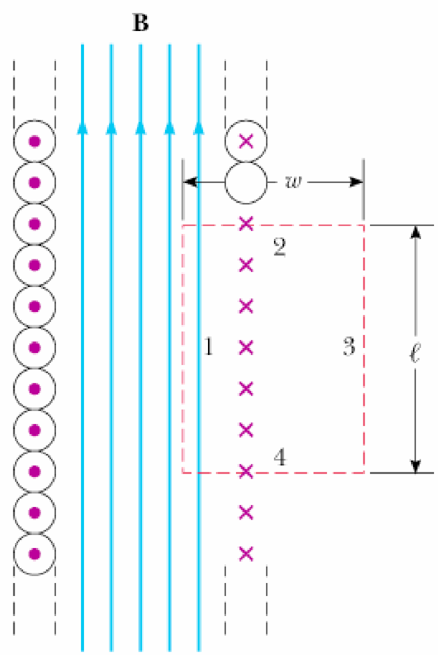

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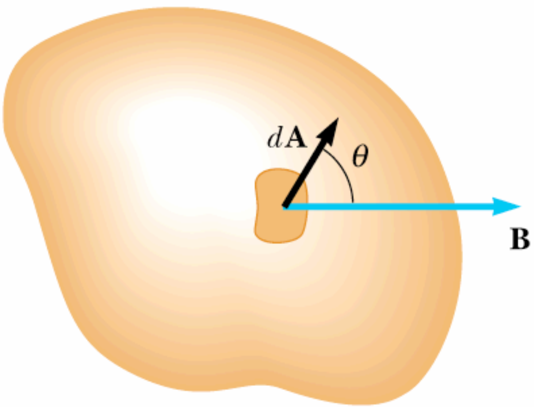
Figure 30.19



Magnetic Flux

$$\Phi_B = \int \mathbf{B} \cdot d\mathbf{A}$$

Gauss' Law in Magnetism

No isolated magnetic monopoles:

$$\oint \mathbf{B} \cdot d\mathbf{A} = 0$$

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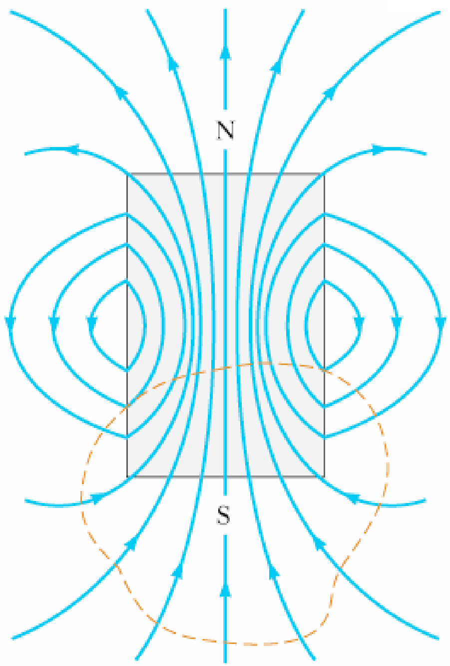
Figure 30.22



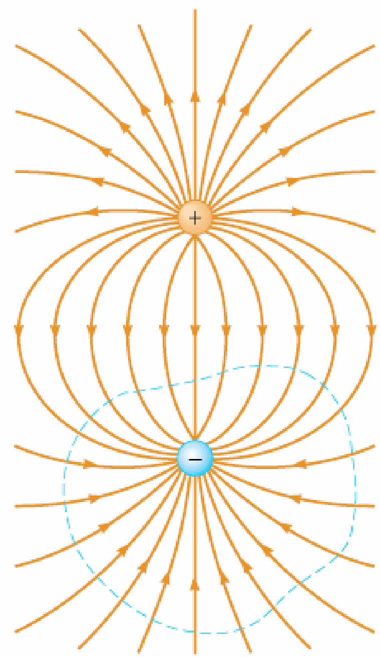


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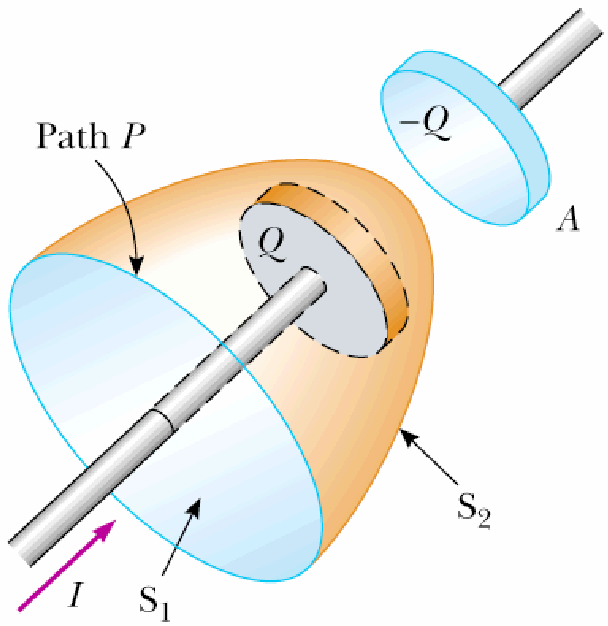
Figure 30.24



Ampere, Maxwell and Diplacement Current

Electric flux in the region between the plates of a capacitor:

$$\Phi_E = \int \mathbf{E} \cdot d\mathbf{A} = EA = \frac{\sigma}{\epsilon_0} A = \frac{Q}{\epsilon_0}$$

We can define the **displacement current** I_d in the region of the electric filed as:

$$I_d = \frac{dQ}{dt} = \epsilon_0 \frac{d\Phi_E}{dt}$$

A time varying electric field behaves similar to a current of magnitude $\epsilon_0 \frac{d\Phi_E}{dt}$

Ampere-Maxwell Law

$$\oint \mathbf{B} \cdot d\mathbf{s} = \mu_0 (I + I_d) = \mu_0 I + \mu_0 \epsilon_0 \frac{d\Phi_E}{dt}$$

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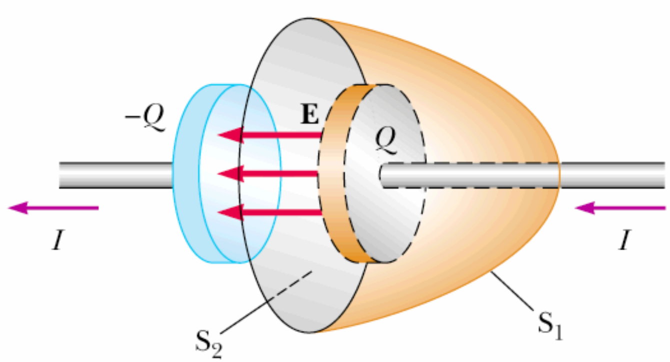
Figure 30.25



Faraday's law

- An **emf** is induced in a circuit when the magnetic flux through that circuit is changing:

$$\varepsilon = -\frac{d\Phi_B}{dt} \tag{1}$$

$$\varepsilon = -\frac{d}{dt}(B\,A\cos\theta)$$

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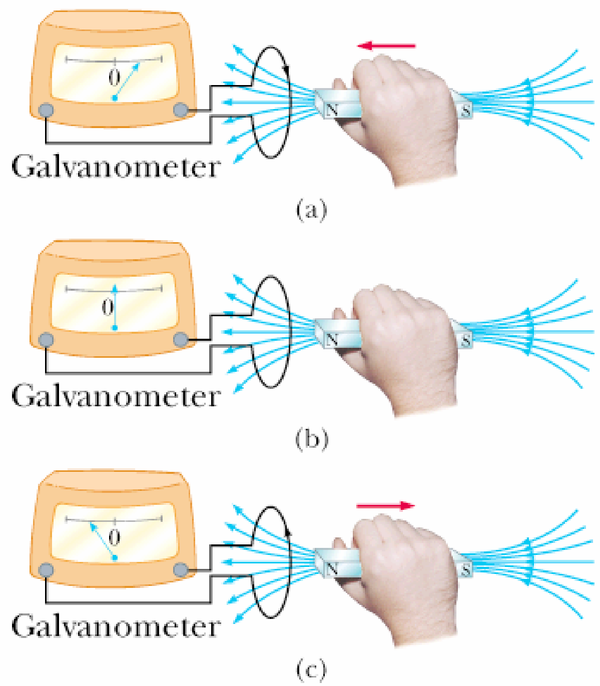
Figure 31.1



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Motional *EMF*

- The magnetic flux through the circuit:

$$\Phi_B = Blx$$

- The induced motional *emf*

$$\varepsilon = -\frac{d\Phi_B}{dt}$$
$$= -\frac{d}{dt}(Blx) = -Bl\frac{dx}{dt}$$
$$= -Blv$$

- The current in the circuit:

$$I = \frac{|\varepsilon|}{R}$$
$$= \frac{BLV}{R}$$

- Due to this current in the moving bar, it experiences a magnetic force (F_B) that opposes the motion; need to apply an equal and opposite force (F_{app}) to maintain the velocity:

$$F = IlB$$

- Work required to move the bar (and the associated power)

$$W = (F_{app})x = (IlB)x$$
$$P = \frac{d}{dt}W = (F_{app})v = (IlB)v = \frac{B^2l^2v^2}{R} = \frac{\varepsilon^2}{R}$$

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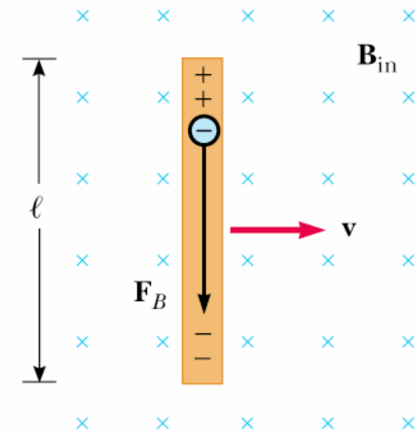
Figure 31.8

(2)



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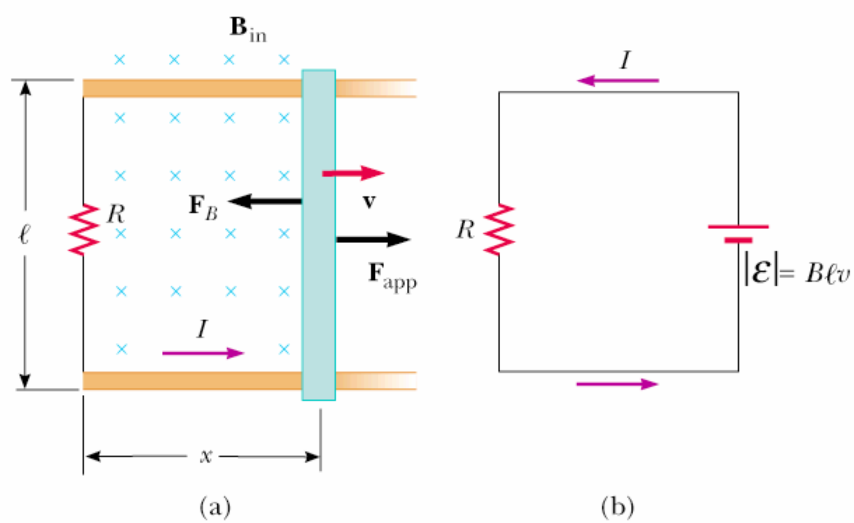

Example 31.4:
Find the motional *emf* between the ends of the bar

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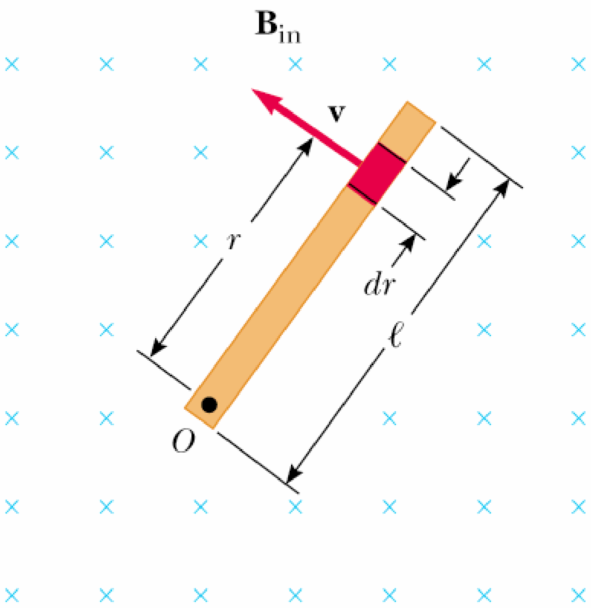
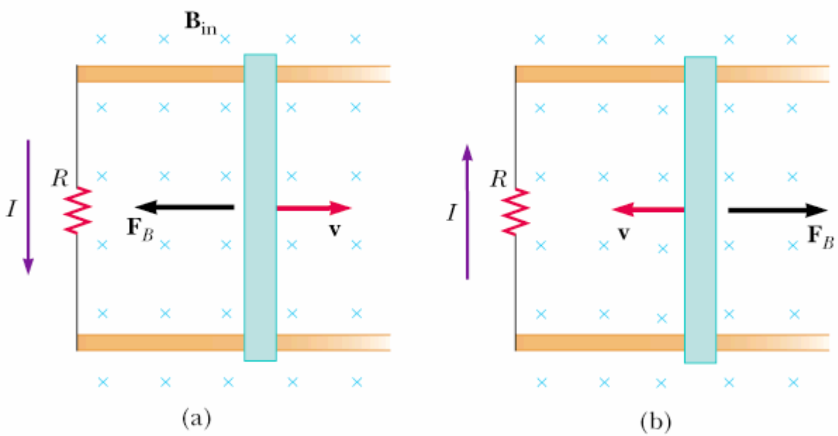
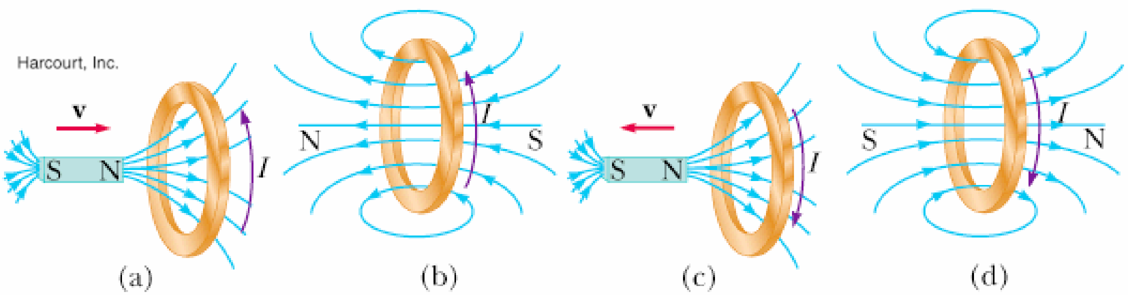
Figure 31.10



Lenz's law

The polarity of the induced *emf* is such that if tends to produce a magnetic flux to oppose the change in magnetic flux through the area enclosed by the current loop

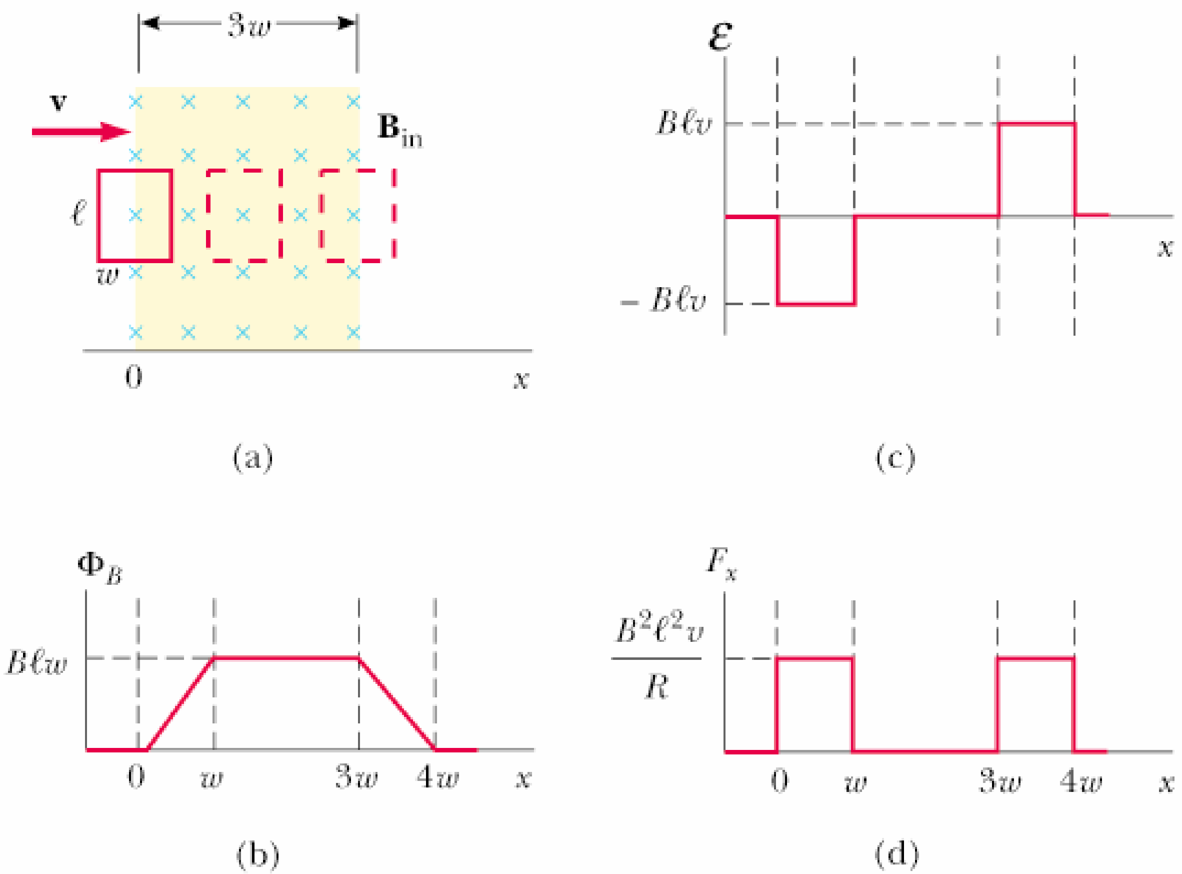




Example 31.7: A loop moving through a magnetic field;

A rectangular loop of dimensions *l* and *w* and resistance *R* moves with constant speed v to the right, passing through a uniform magnetic field **B**. *x* is defined as the position of the front leg of the loop. Plot as a function of *x*:

a. Magnetic flux through the loop
b. The induced motional *emf*
c. The external force required to keep *v* constant.



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