Issue 78 – June 2026

www.scienceinschool.org

Generating induced currents

Activity 2 explanation sheet

Varying the coil surface

The copper rod and the U-shaped element form an electrical circuit. The magnets create a near uniform magnetic field through this circuit. As the rod rolls over the rails at a velocity *v*, the surface area enclosed by the circuit becomes larger, as does the magnetic flux through that surface. As a result, an EMF is induced in the circuit and current will flow through it for as long as the flux continues to change.

The surface enclosed by the copper circuit can be expressed as *L* × x, where *L* is the fixed length and x is the variable length (see figure 3b in the main text), which changes as the rod moves. Applying this to the equation for the magnetic flux ($\emptyset_m = \vec{B} \cdot \vec{S} \cdot \cos \Theta$) we can calculate the magnetic flux:

$$\emptyset_m = \vec{B} \cdot \vec{S} = B \cdot S \cdot \cos 0° = B \cdot S = B \cdot L \cdot x.$$

Now, applying Faraday's law of induction, we get

$$\varepsilon_{ind} = -\frac{d\emptyset_m}{dt} = -\frac{d(B \cdot S)}{dt} = -\frac{d(B \cdot L \cdot x)}{dt} = -B \cdot L \cdot \frac{dx}{dt} = -B \cdot L \cdot v.$$

As we can see from this expression, the EMF in this case depends on the speed at which the copper rod moves over the rails.

The current (*I*) induced by this EMF is given by

$I_{ind} = -\frac{B \cdot L \cdot v}{R}$, where *R* is the resistance in the circuit.

According to Lenz's law, the direction of the current induced by a change in magnetic flux is such that it generates a magnetic field which opposes the variation in flux.
In our case, if we let the rod roll to the right, the surface area of the circuit increases, as does the

magnetic flux passing through it. If the magnetic field points downwards towards the wooden block, as shown in figure 6b in the main text, the induced current will oppose the increase in magnetic flux by creating a magnetic field pointing upwards, away from the wooden block. According to the right-hand rule, the induced current will therefore flow anticlockwise.

As the rod is immersed in a magnetic field ($\vec{B}$) and has a current (*I*) flowing through it, it will experience a magnetic force F_m. According to Laplace's Law,

$$\vec{F}_m = I(\vec{L} \cdot \vec{B})$$

Since $\vec{L}$ and $\vec{B}$ are perpendicular, the magnitude of the force is $F_m = ILB$. According to the right-hand rule, as $\vec{L}$ follows the direction of the (counterclockwise) current and $\vec{B}$ points into the page (refer to figure S4), the cross product of $\vec{L}$ and $\vec{B}$ yields a magnetic force that points towards the left, which opposes the motion of the rod.

In summary, as the rod rolls to the right, a magnetic force pointing to the left appears, which slows down the rod.

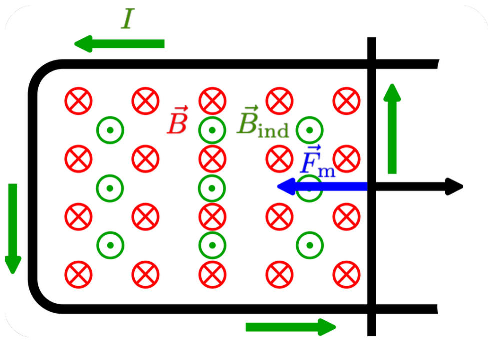

Figure S4: The rightward motion of the current-carrying rod immersed in field $\vec{B}$ induces a counterclockwise current I and field $\vec{B}_{ind}$. A magnetic force $\vec{F}_m$ appears, opposing the rightward motion of the rod.
Image courtesy of the authors

If we were to roll the rod to the left, the surface area of the circuit would decrease, and so would the magnetic flux through it. The induced current would oppose this decrease by generating a magnetic field in the same direction as the original field (into the page), i.e., a clockwise current. Again, the magnetic force would point towards the right, opposing the motion of the rod.