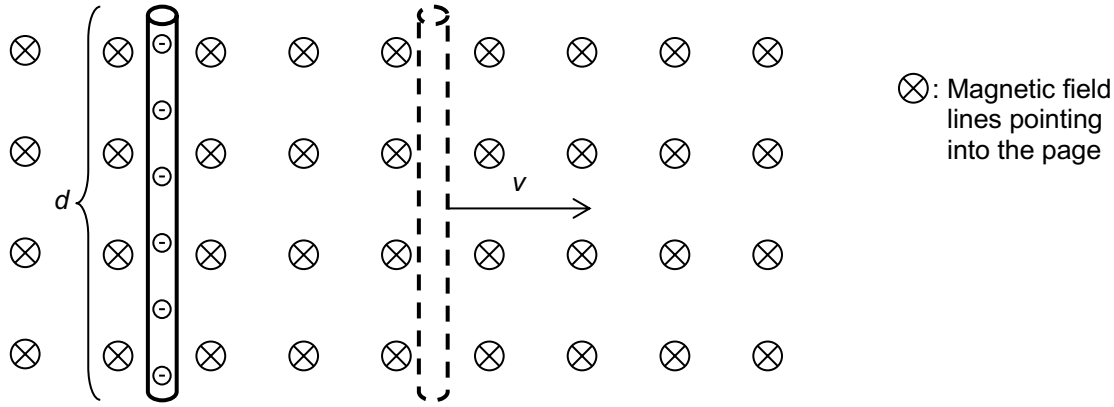
Electromagnetic induction

A conductor is moving in a magnetic field

A metal rod of length *d* moves perpendicular to a magnetic field with velocity *v*:



1. Draw the magnetic force acting on the electrons that are travelling in the rod.
2. The electrons are displaced due to the magnetic force acting upon them (the atomic cores remain at their fixed positions). Draw the distribution of charge in the moving (dashed) rod.
3. The separated charge in the rod produces a field in the rod. What is the field (*magnetic field, gravitational field, soccer field, electric field*...)?
4. This field exerts a force on the displaced electrons in the rod. What is the direction of this force?
5. Draw the two forces acting on one of the electrons as arrows. These forces have the same magnitude, but not the same direction!
6. Find the formula that describes how the voltage between the ends of the metal rod depends on the magnetic field *B*, the length of the rod *d* and the velocity *v* (for formulae, see back):

a) What is the magnetic force acting on a charge *q* moving perpendicular in a magnetic field *B* with velocity *v*?

$F_{magnetic}$ =

b) What is the electric force acting upon a charge *q* in an electric field *E*?

$F_{electric}$ =

c) The two forces balance, hence $F_{magnetic} = F_{electric}$. Substitute the right sides of a) and b) into this equation and solve for the electric field *E*:

= = $\Rightarrow$ *E* =

d) What is the voltage *U* between two points with the distance *d* in a uniform electric field E?

U =

e) In the above equation, substitue *E* using the right side of equation d):

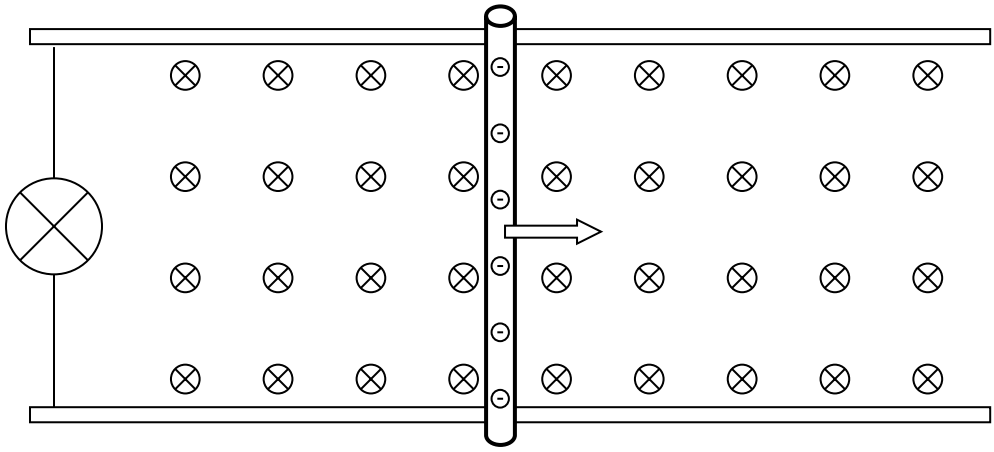
U_{ind} =

U_{ind} is the voltage induced between the ends of a conductor of length *d* moving with constant velocity *v* perpendicularly to a uniform magnetic field *B*.

Induced current

Here, the metal rod, that is moving perpendicularly to a magnetic field, is sliding on conducting rails that form part of a closed circuit. The electrons flow around the circuit and through the light bulb (see picture). Mechanical energy is converted to electric energy and then to radiant energy. This is an example of a very simple electric generator.

Questions:
- what is the direction of the flow of electrons induced by the movement of the rod in the magnetic field?
- what is the direction of the magnetic force acting on the induced flow of electrons?



1. Draw the direction in which the electrons flow around the circuit, as the rod is moving to the right.
2. Draw the direction of the force acting on the induced flow of electrons.
3. Does the force described in 2. accelerate or decelerate the rod?
4. Explain Lenz' law:

The direction of the induced current always opposes the cause that induces the current.

a) What is the cause that induces the current? (What do you have to do for the electrons to flow around the circuit?)

b) What is the effect of the induced current? (What is the direction of the force acting on the rod if you perform a)? What force is it?)

c) Does the effect of the induced current oppose its cause?

Formulae:

$F_{magnetic} = q \cdot v \cdot B \quad ([v \perp B] \perp F)$ $\qquad \vec{E} = \frac{\vec{F}}{q}$ $\qquad U = E \cdot d$