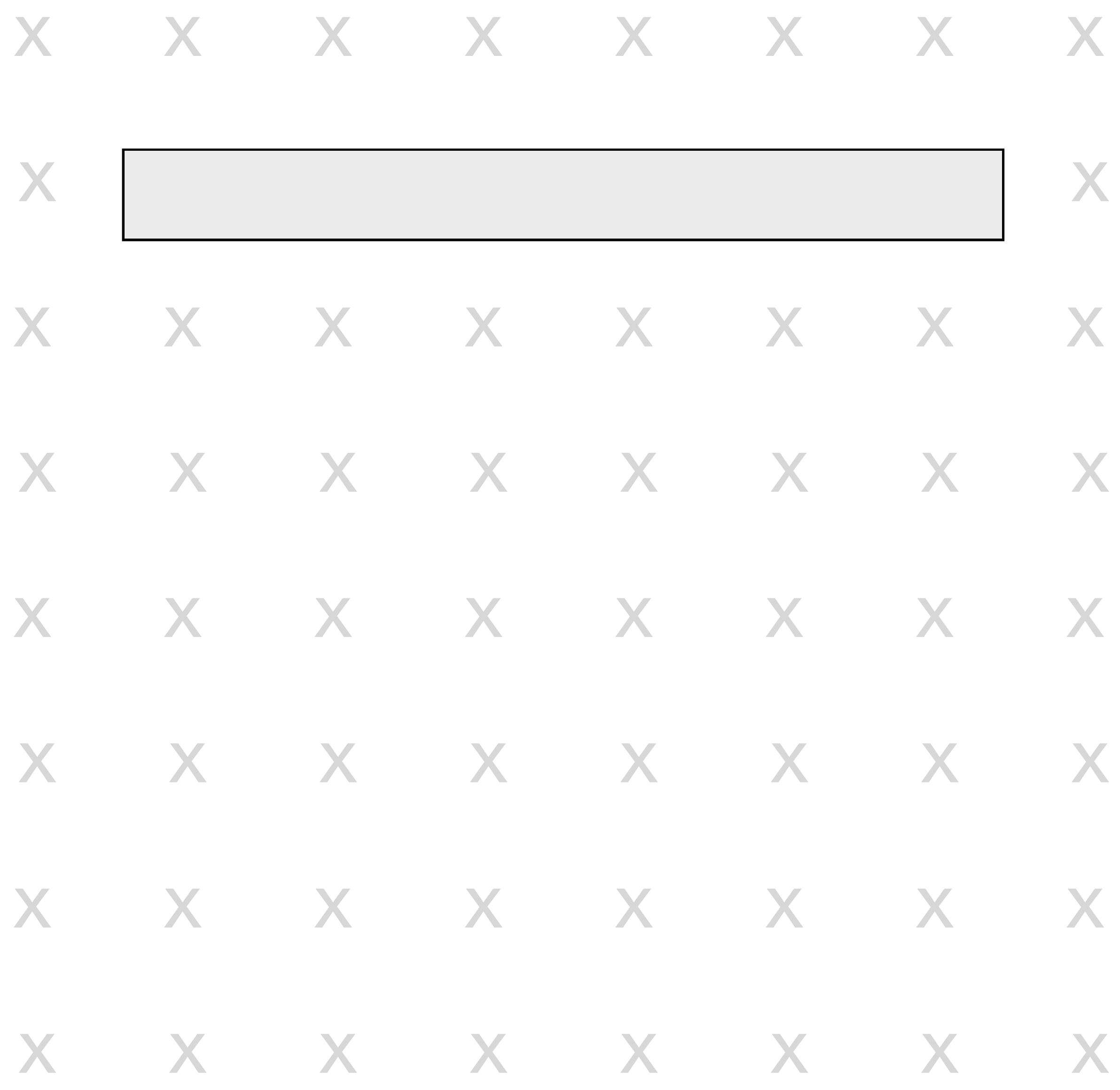
Electromagnetic induction

- Voltage across a moving rod
- Induced current - opposes changing flux
- Magnetic flux
- Lenz's law
- Induced EMF
- EMF calculations
- EMF vs flux graphs
- AC generator (alternator)

Voltage across a moving rod

- Recall the force on a charged particle moving through a field.
- A rod moving in a magnetic field will have a separation of charge along its length (or width).
- By the right-hand slap rule, + charge will be pushed to the right here.



Magnitude of induced voltage

- eg a 1m rod moving at 1m/s in Earth's field ~ 10^{-5}T

$$F = qvB$$

$$W = Fx = qvBL$$

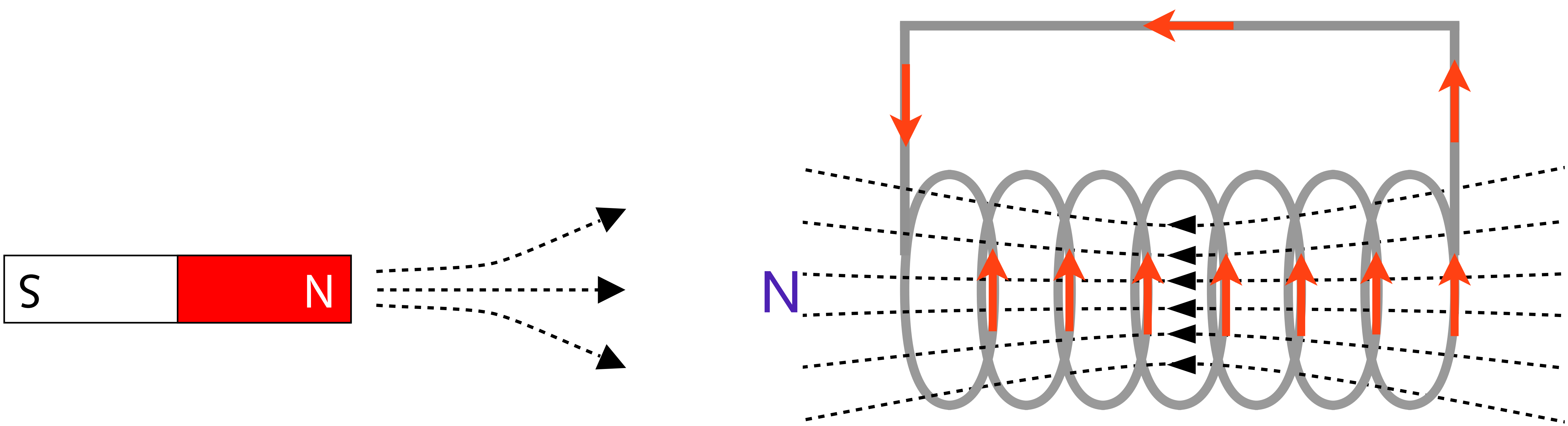
$$V = \frac{W}{q} = \frac{qvBL}{q} = BLv$$

$$V = BLv = (10^{-5}T)(1m)(1m/s)$$

$$V = 0.01mV$$

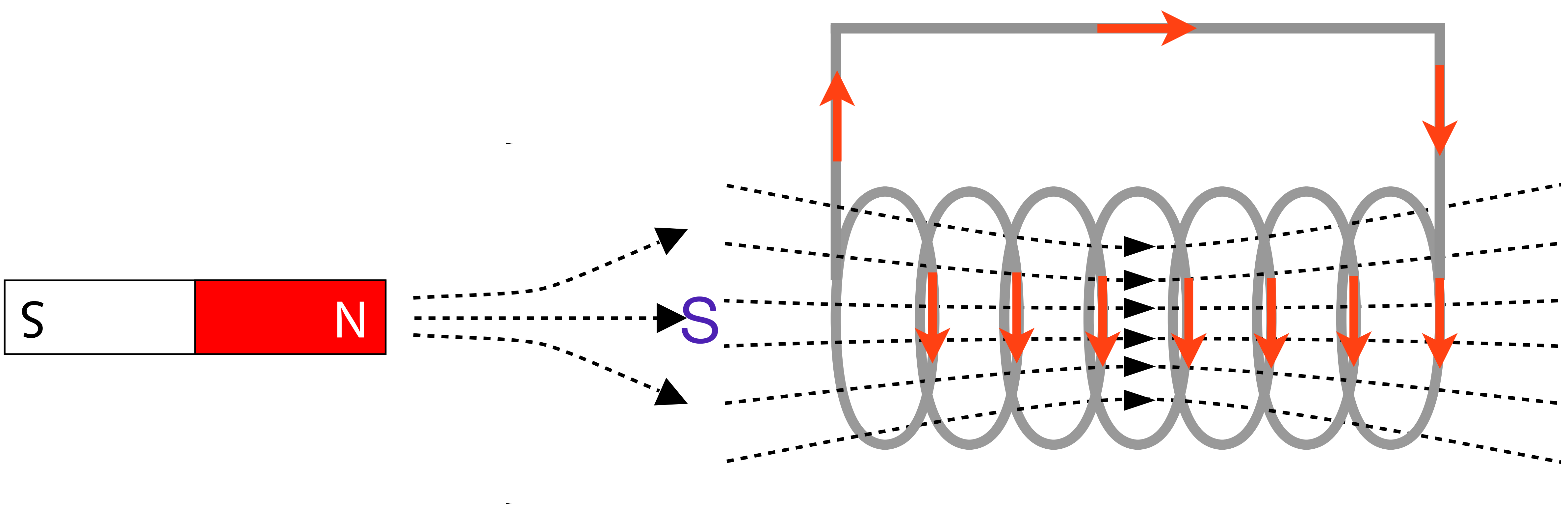
Induced current - opposes changing flux

- Pushing the north pole into a solenoid will induce a current that makes a north pole to oppose the magnet going in.



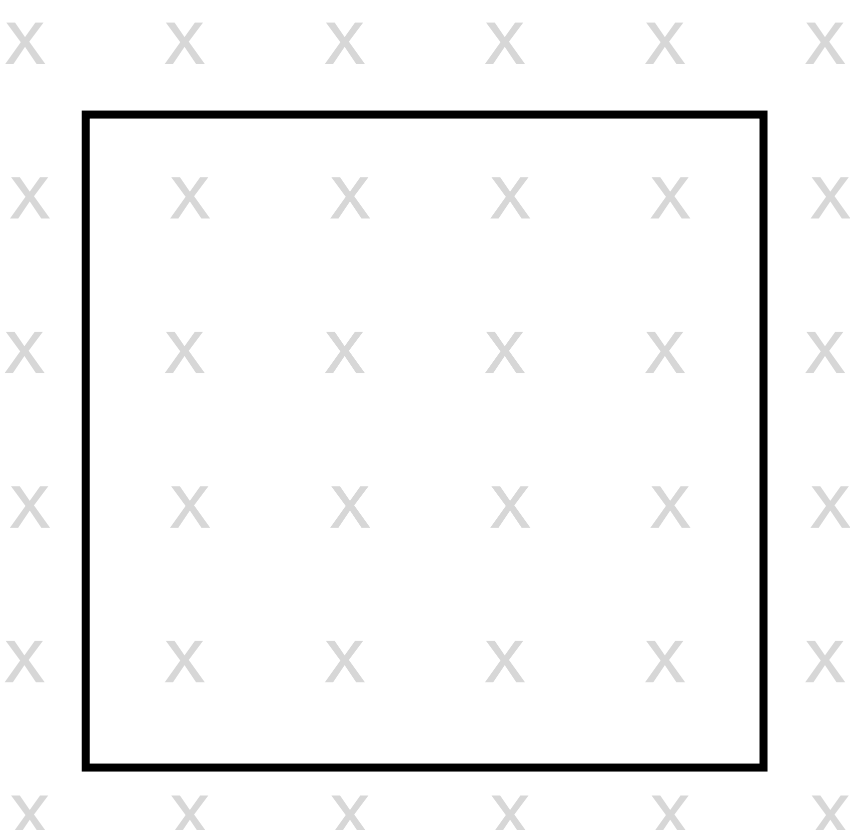
Induced current - opposes changing flux

- Pulling the north pole out of a solenoid will induce a current that makes a south pole to oppose the magnet going out.



Magnetic flux

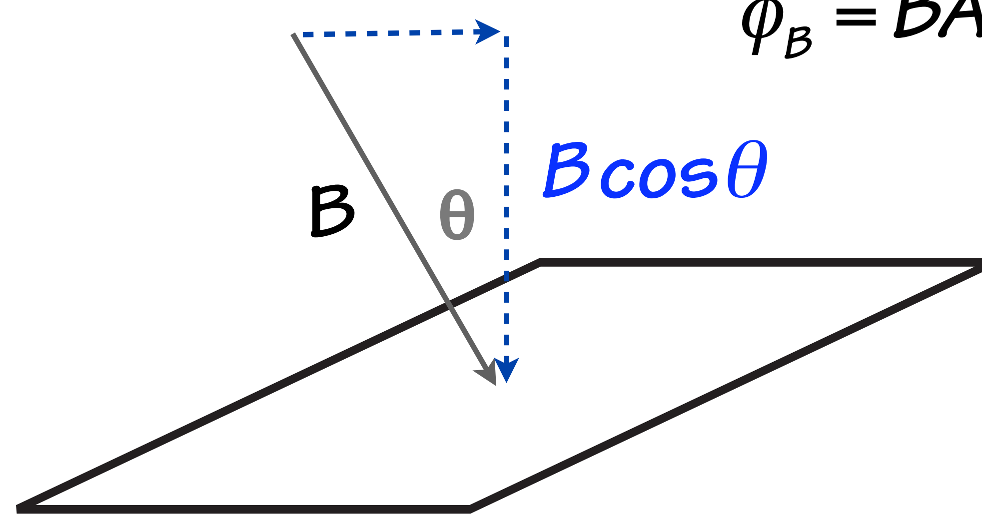
- Magnetic flux (ΦB) is a measure of the number of field lines that pass through an area.
- ΦB = B A , Unit = Tm^2 (Weber, Wb)
- *eg 20 cm x 20 cm square, 0.1 T magnetic field*



$$\phi_B = (0.2m)^2 \times (0.1T)$$

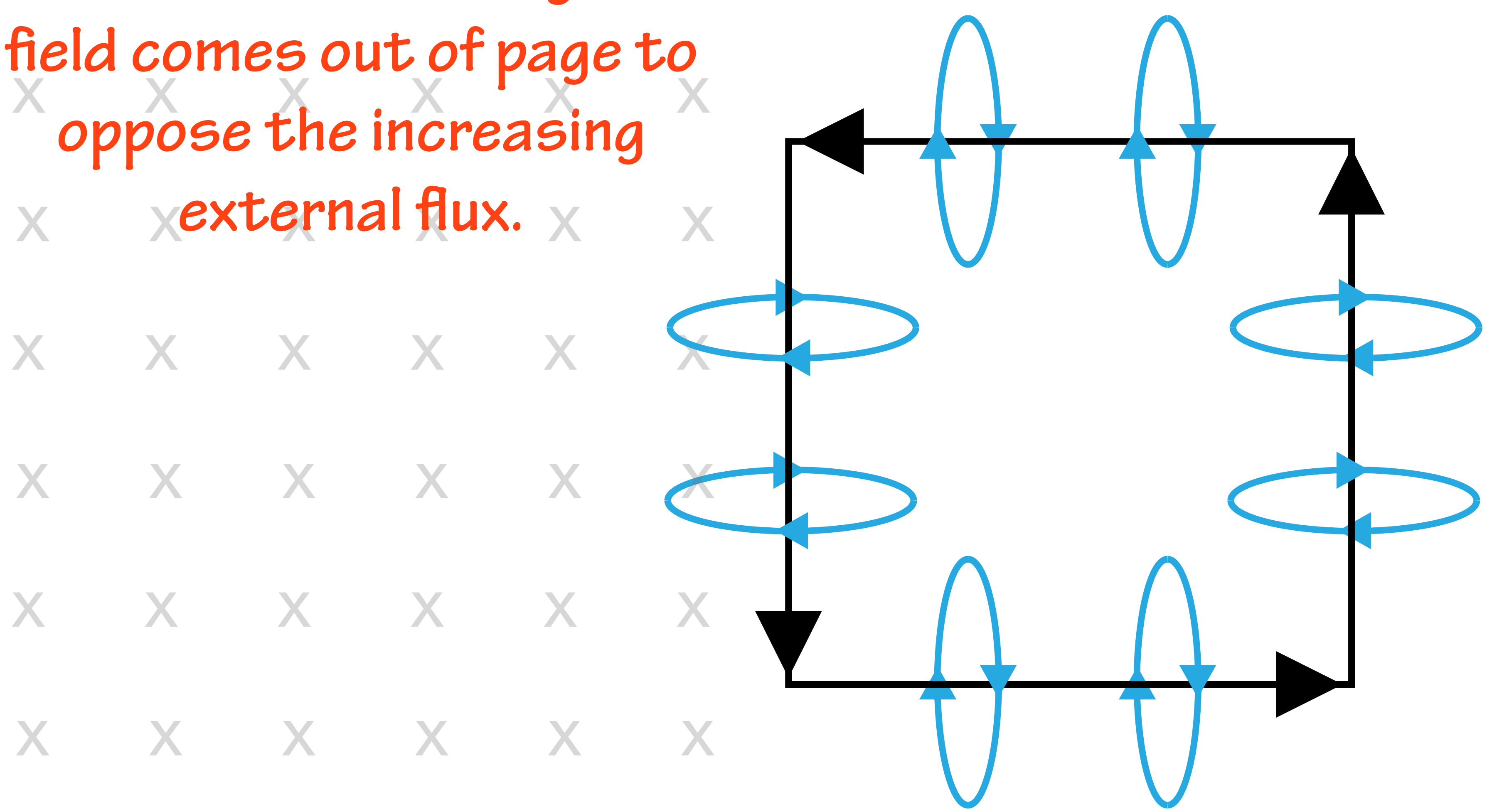
$$\phi_B = 0.004Wb$$

$$\phi_B = BA\cos\theta$$



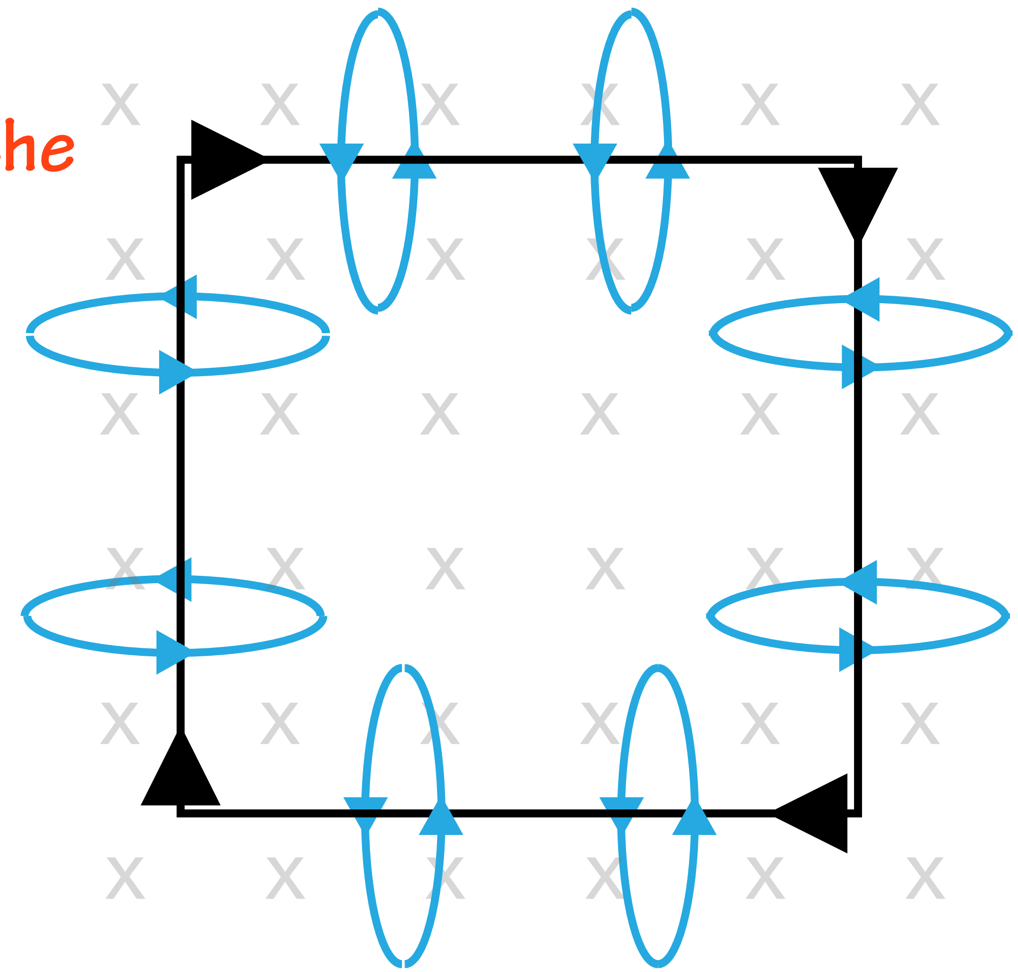
- Changes to magnetic flux induce currents.

Induced current - magnetic field comes out of page to oppose the increasing external flux.



Magnetic flux

Induced current - magnetic field goes into page to oppose the decrease of the external flux.



Lenz's law

- Faradays law: "The EMF is produced that is proportional to the rate of change of magnetic flux."
- Lenz's law: " The induced current produces its own magnetic field to oppose changes to magnetic flux. "

Number of turns of wire

Magnitude of induced EMF (V)

$$EMF = -\frac{n\Delta\phi_B}{\Delta t}$$

Change in flux (Wb) per time (s)

Negative sign: induced current opposes change in flux

Induced EMF

Voltage can be induced by:

- changing field strength.
- changing area of wire.
- changing direction of field / wire orientation.

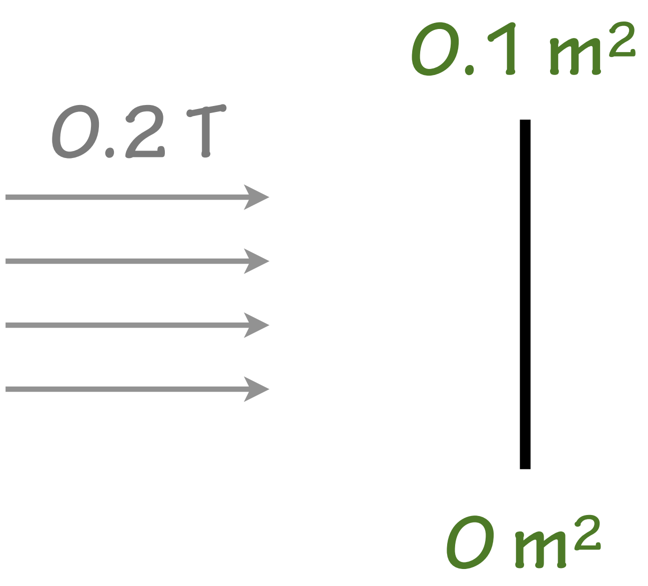
Higher EMF (voltage) from:

- stronger magnetic field.
- faster movement.
- greater area.
- multiple loops (n).

EMF calculations

- A wire loop with 100 turns of wire & an area of $0.1 m^2$ is rotated through a field of 0.2T at a rate of 5Hz.

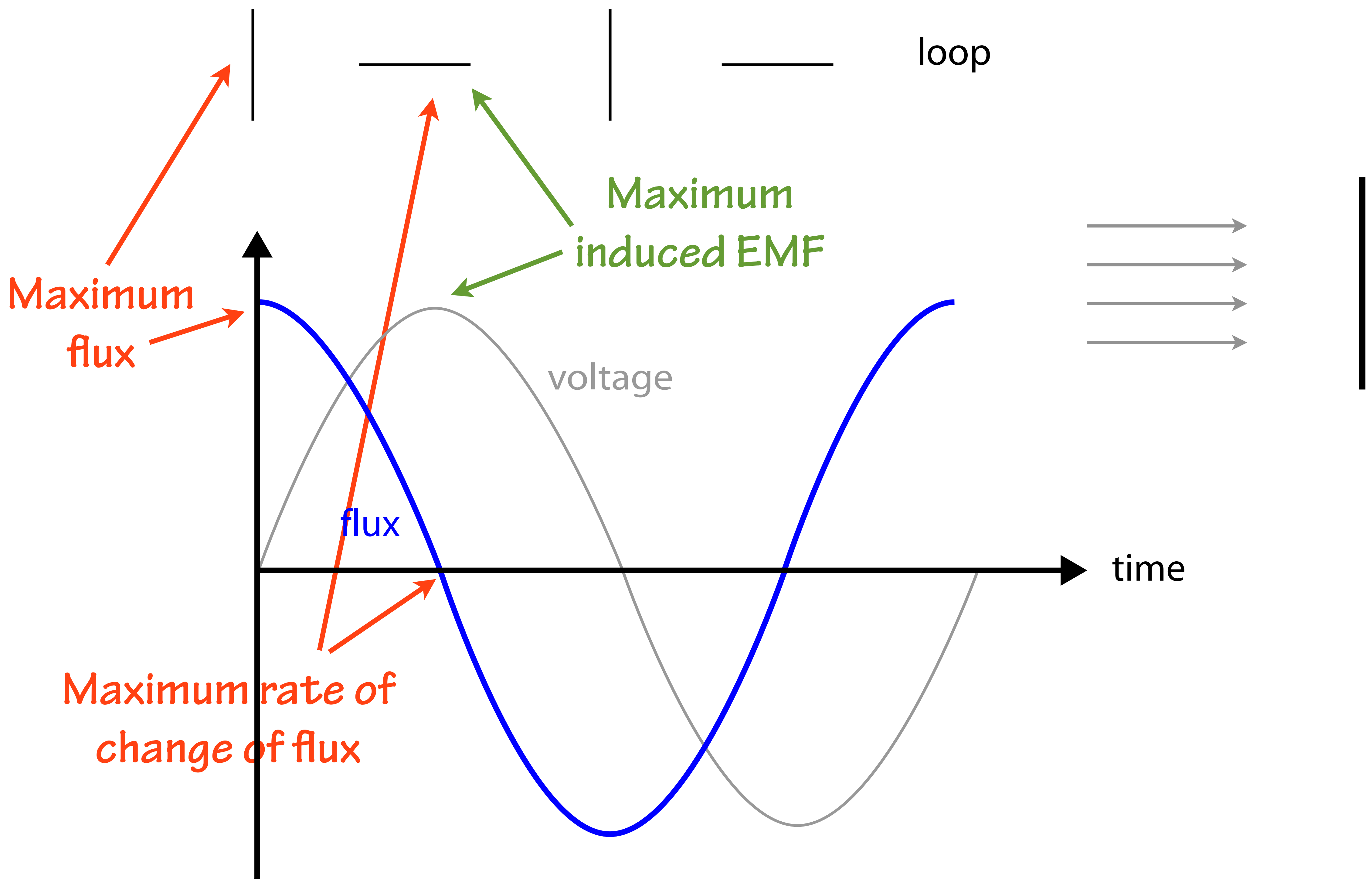
- The magnitude of B changes from +0.2 T to 0.0 T
- This takes a time of 0.25 x 0.20 s = 0.05 s



$$EMF = -\frac{n\Delta\phi_B}{\Delta t} = -\frac{100 \times (-0.2T)(0.1m^2)}{0.05s}$$

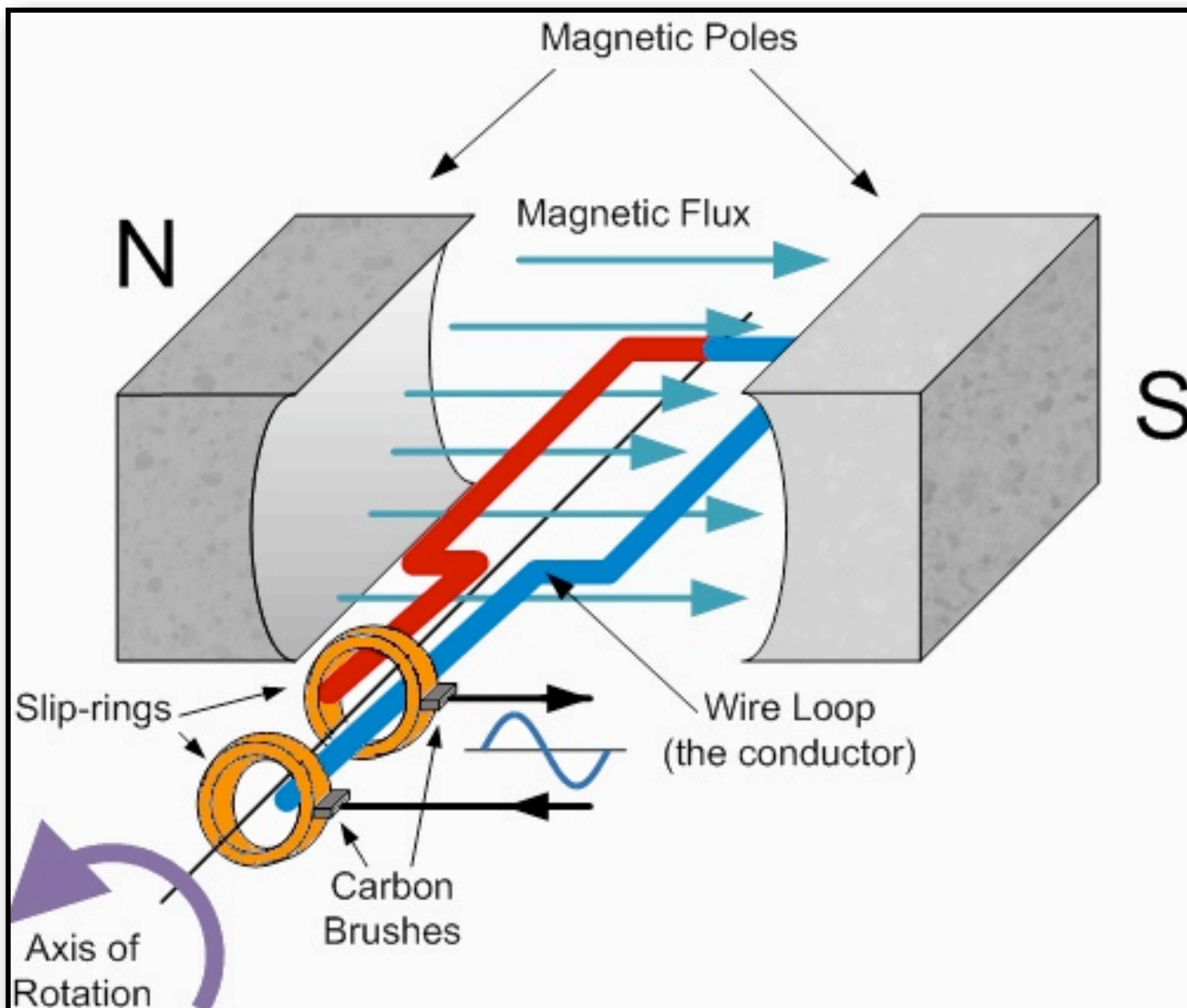
$$EMF = 40V$$

EMF vs flux graphs



AC generator (alternator)

- Contact is at slip rings - one side is always in contact with the same ring.
- The direction of the current & voltage will alternate every half cycle.
- Doubling rate of revolution doubles frequency and voltage.



http://www.electronics-tutorials.ws/accircuits/sinusoidal-waveform.html

Generator