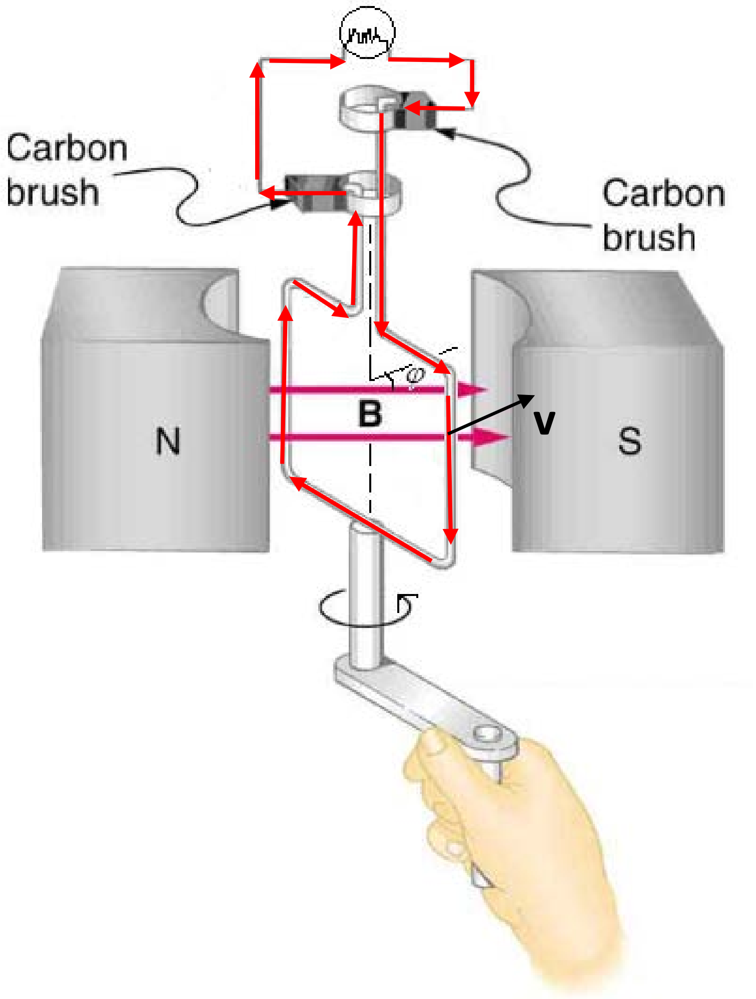
D.1 Generators



Say we have an N = 100 turn, 10cm×10cm square loop,
rotating in a B = 2T magnetic field,
with frequency f = 60Hz rotating clockwise,
connected to an R = 200Ω lightbulb.

What is the maximum induced effective potential difference?

$$\xi_{eff} = NBA\omega \sin\varphi \longrightarrow \xi_{\max} = NBA\omega = (100)(2\mathrm{T})(0.10^2\,\mathrm{m}^2)(2\pi \cdot 60\mathrm{Hz}) = 754\mathrm{V}$$

What's the max induced current; which way past the lightbulb would it flow, in the present orientation?

$$i_{\max} = \frac{\xi_{\max}}{R} = \frac{754\mathrm{V}}{200\Omega} = 3.8\mathrm{A}$$

The direction is easiest to ascertain by considering where $\mathbf{F}_B = q\mathbf{v}\times\mathbf{B}$ points on the front wire:

right

What max power is dissipated by the lightbulb?

$$P_{\max} = i_{\max}^2 R = (3.8\mathrm{A})^2(200\Omega) = 2.9\mathrm{kW}$$

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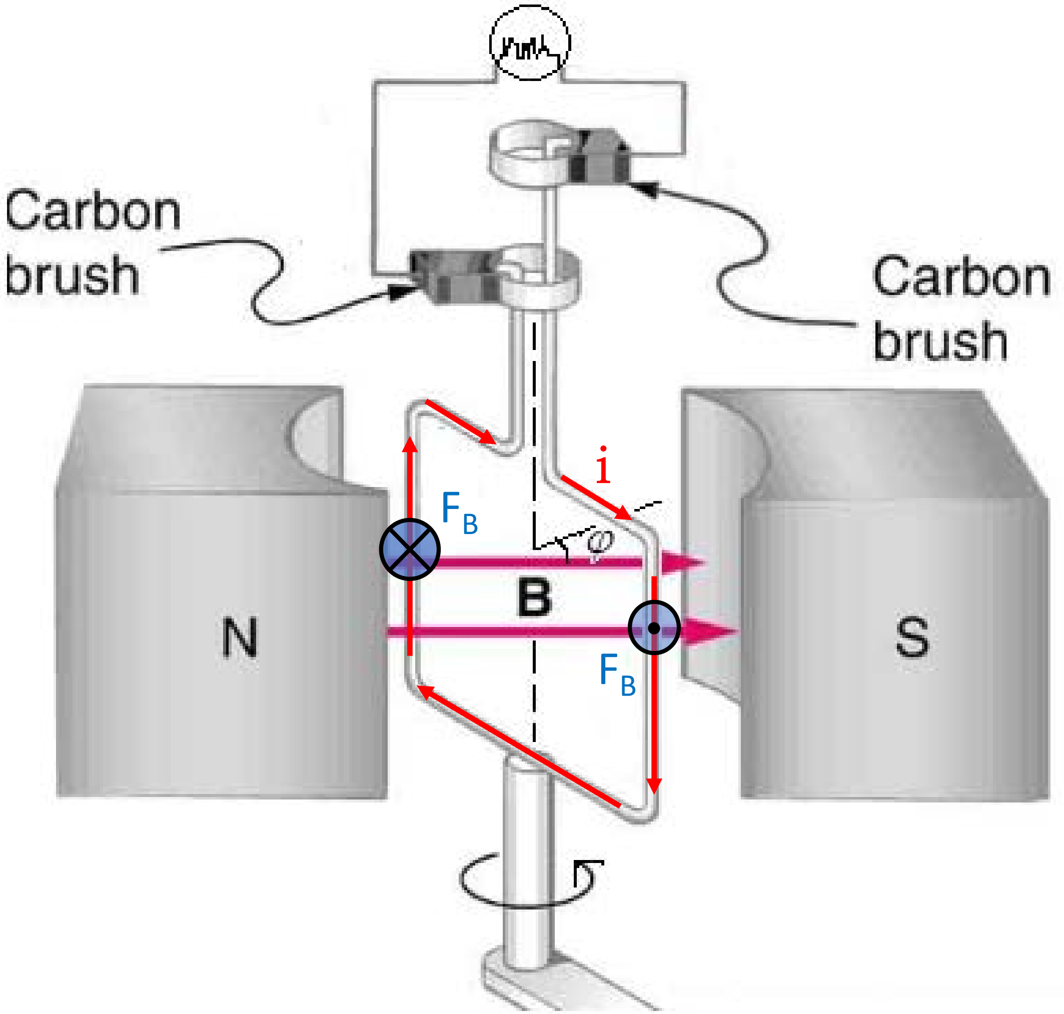

Say we have an N = 100 turn, 10cm×10cm square loop,
rotating in a B = 2T magnetic field,
with frequency f = 60Hz rotating clockwise,
connected to an R = 200Ω lightbulb.

This power isn't free.
While the magnetic field will generate a power-producing current,
Simultaneously, it'll generate a power-sapping counter torque on the loop,
in effect, stealing power from you, to put power in the current.
What is the max torque? And what max power does the B-field steal?

$$\boldsymbol{\tau}_B = \mathbf{r}\times\mathbf{F}_B + \mathbf{r}\times\mathbf{F}_B$$

$$= \left(\frac{l}{2}\right)(N\cdot lIB\sin\varphi)(\mathrm{CW}) + \left(\frac{l}{2}\right)(N\cdot lIB\sin\varphi)(\mathrm{CW})$$

$$= (Nl^2 IB\sin\varphi)(\mathrm{CW})$$

$$= \mu B\sin\varphi \qquad \mu\,(\text{magnetic moment}) = NIA$$

So $\tau_{\max} = \mu_{\max} B\sin 90^\circ = (NI_{\max}A)(B)\sin 90^\circ = (100\cdot 3.8\mathrm{A}\cdot 0.10^2\,\mathrm{m}^2)(2\mathrm{T}) = 7.6\mathrm{N}\cdot\mathrm{m}$

$P_{steal\,(\max)} = \boldsymbol{\tau}_B\cdot\boldsymbol{\omega} = -(7.6\mathrm{N}\cdot\mathrm{m})\cdot(2\pi\cdot 60\mathrm{Hz}) = -2.9\mathrm{kW}$ So the powers are indeed equal/opposite.