What is the magnetic flux through 1 m^2 of ground in Idaho?

10. An electric generator consists of a rectangular coil of wire rotating about its longitudinal axis which is perpendicular to a magnetic field of 2.0×10^{-2} T. The coil measures 10.0 cm $\times$ 20.0 cm and has 120 turns of wire. The ends of the wire are connected to an external circuit. At what speed (in rev/s) must you rotate this coil in order to induce an alternating emf of amplitude 12.0 V between the ends of the wire?

See the "Quantitative Prelecture Video" for a more typical test problem.

Here is a similar simplification: How quickly must you rotate from 0° to 180° to have an average emf of 12.0 V? What rotation speed would that imply?

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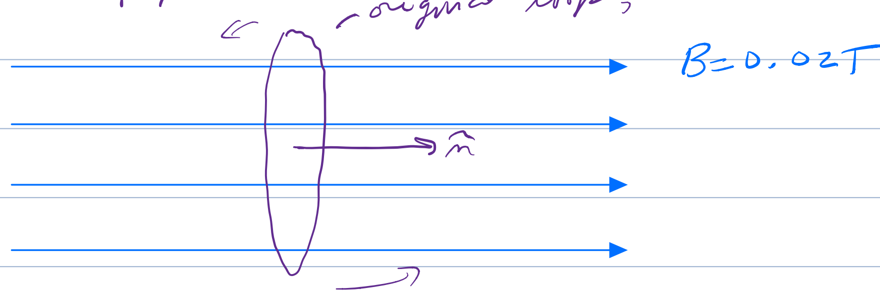
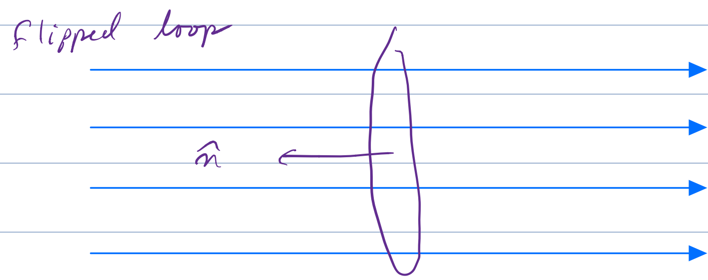




Area = 10 cm × 20 cm = 0.10 m × 0.2 m = $0.02\, m^2$

N = 120 turns

original flux: $\Phi_i = NBA\cos 0°$

$= (120)(0.02T)(0.02m^2)(1)$

$\Phi_i = 0.048\ Tm^2$

final flux: $\Phi_f = NBA\cos 180°$

$= (120)(0.02T)(0.02m^2)(-1)$

$\Phi_f = -0.048\ Tm^2$

Faraday's Law: $\mathcal{E} = -\frac{\Delta\Phi}{\Delta t}$

$$\mathcal{E} = -\frac{(\Phi_f - \Phi_i)}{\Delta t} = \frac{0.096\ Tm^2}{\Delta t}$$

want $\mathcal{E} = 12.0\ V$

$$\therefore \quad \Delta t = \frac{0.096\ Tm^2}{12.0\ V} = 0.008\ s$$

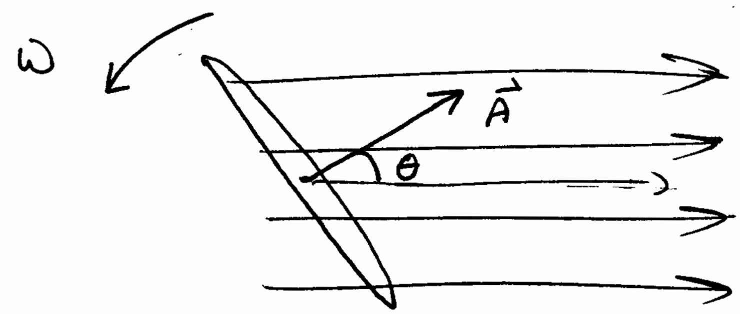
This is $\frac{1}{2}T$ for a full rotation

$\therefore \quad T = 0.016\ s$

$f = 1/T = 62.5\ Hz$

(Calculus version below gives 39.8 Hz, so the assumption that derivative is approximated by the average change is OK, but not great.)

e.g. generator. (#10)



uniform $\vec{B} = 2 \times 10^{-2}\, T\, \hat{i}$

Loop, area $0.02\, m^2 = A$

$N = 120$ turns.

want $\mathcal{E}_{max} = 120\, V$

frequency of rotation $f = ?$

$$\Phi_B = N \int \vec{B} \cdot d\vec{A} = N \int B\, dA \cos\theta = N B \cos\theta \int dA$$

$$\Phi_B = NBA \cos\theta$$

$$\mathcal{E} = -\frac{d\Phi_B}{dt} = -NBA \sin\theta \left(\frac{d\theta}{dt}\right)$$

$\frac{d\theta}{dt} = \omega =$ angular velocity

Derivatives won't be on our test!

$$= -NBA \sin(\omega t) \cdot \omega$$

$$\mathcal{E} = -NBA\, 2\pi f \sin(\omega t)$$

$\sin(\omega t)$ oscillates -1 to $+1$

~~want~~ $\mathcal{E}_{max} = NBA\, 2\pi f$

Want $\mathcal{E}_{max} = 120$, 12.0 ~~120~~ $= (120)(0.02)(0.02)\, 2\pi f$

$39.8\ Hz = f$