CHAPTER 23

1. $A = 8\,cm^2 = 8 \cdot 10^{-4}\,m^2$

$B_1 = 0.5\,T$

$B_2 = 2.5\,T$

$\Delta t = 1\,s$

$R = 2\,\Omega$

$\Delta B = B_2 - B_1 = 2T$

$\Delta \Phi = A \cdot \Delta B = 1.6 \cdot 10^{-3}\,Wb$

$|\mathcal{E}| = \dfrac{|\Delta \Phi|}{\Delta t} = 1.6 \cdot 10^{-3}\,V$

$I = \dfrac{|\mathcal{E}|}{R} = \underline{8 \cdot 10^{-4}\,A}$

3. $B_1 = 1.6\,T$

$B_2 = 0$

$A = 0.2\,m^2$

$N = 200$

$R = 20\,\Omega$

$\Delta t = 20\,ms = 20 \cdot 10^{-3}\,s$

$|\Delta B| = |B_2 - B_1| = 1.6\,T$

$|\Delta \Phi| = N \cdot A \cdot |\Delta B| = 64\,Wb$

$|\mathcal{E}| = \dfrac{|\Delta \Phi|}{\Delta t} = 3200\,V$

$I = \frac{|\mathcal{E}|}{R} = \underline{160\,A}$

6. $N_{coil} = 15$ $R_{coil} = 10cm = 0.1m$

$n_{sol} = 10^3$ turns/m $R_{sol} = 2cm = 0.02m$

$I_{sol}(t) = (5A)\sin(120t)$

$B_{sol}(t) = \mu_0 n_{sol} I_{sol}(t)$

There is magnetic field only inside the solenoid:

$A = \pi R_{sol}^2 = 1.26 \cdot 10^{-3} m^2$

$\phi(t) = N_{coil} A\, B_{sol}(t) = (1.18 \cdot 10^{-4} Wb)\sin(120t)$

$\mathcal{E}(t) = -\frac{d\phi(t)}{dt} = \underline{-(1.4 \cdot 10^{-2} V)\cos(120t)}$

7. $N = 30$

$R = 4cm = 4 \cdot 10^{-2} m$

Resistance $= 1\Omega$

$B = 0.01t + 0.04t^2$

$t = 5s$

$A = \pi R^2 = 0.005 m^2$

$\phi = NAB = 0.15(0.01t + 0.04t^2) = 1.5 \cdot 10^{-3}(t + 4t^2)$

$\mathcal{E} = -\frac{d\phi}{dt} = -1.5 \cdot 10^{-3}(1 + 8t)$

$\mathcal{E}(5s) = -61.8 \cdot 10^{-3} V$

$|\mathcal{E}(5s)| = 61.8 \cdot 10^{-3} V$

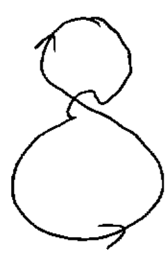
10. $R_1 = 5 cm$

$R_2 = 9 cm$

Resistance/length $= 3 \, \Omega/m$

$\frac{\Delta B}{\Delta t} = 2 T/s$

The induced EMF is as shown (By right hand rule). So the directions are opposite, the EMF in the bigger circle is bigger, so over all the direction of the induced current is:



$A_2 = \pi R_2^2 = 0.025 m^2$

$A_1 = \pi R_1^2 = 0.0078 m^2$

$\Phi_2 = A_2 \cdot B \; ; \; \Phi_1 = A_1 \cdot B$

$|\mathcal{E}_2| = \frac{\Delta \Phi_2}{\Delta t} = A_2 \frac{\Delta B}{\Delta t} \; ; \quad |\mathcal{E}_1| = \frac{\Delta \Phi_1}{\Delta t} = A_1 \frac{\Delta B}{\Delta t}$

$$|\mathcal{E}| = |\mathcal{E}_2| - |\mathcal{E}_1| = (A_2 - A_1)\frac{\Delta B}{\Delta t} \simeq 0{,}035\,V$$

$$l_2 = 2\pi R_2$$

$$l_1 = 2\pi R_1$$

$$l = l_1 + l_2 = 2\pi(R_1 + R_2) \simeq 0{,}88\,m$$

$$\text{Resistance} = 0{,}88\,m \cdot 3\,\Omega/m = 2.64\,\Omega$$

$$I = \frac{|\mathcal{E}|}{\text{Resistance}} \simeq \underline{0{,}013\,A}$$

<u>50.</u>

$$A = 0{,}005\,m^2$$

$$B_1 = 5\,T$$

$$B_2 = 1{,}5\,T$$

$$R = 0{,}02\,\Omega$$

$$\Delta t = 20\,ms = 0{,}02\,s$$

<u>(a)</u> $|\Delta B| = |B_2 - B_1| = 3{,}5\,T$

$$|\Delta\phi| = A\,|\Delta B| = 0{,}0175\,Wb$$

$$|\mathcal{E}| = \frac{|\Delta\phi|}{\Delta t} = 0{,}875\,V$$

$$I = \frac{|\mathcal{E}|}{R} = \underline{43{,}75\,A}$$

<u>(b)</u> $P = I^2 R = \underline{38.3\,W}$

55 $\Phi_B = 3(at^3 - bt^2)\ T\cdot m^2$

$a = 2\ s^{-3}$
$b = 6\ s^{-2}$

$R = 3\Omega$

$t_1 = 0 \qquad t_2 = 2s$

$$|\mathcal{E}| = \left|\frac{d\Phi_B}{dt}\right| = |3(3at^2 - 2bt)| =$$

$$= 3|6t^2 - 12t|$$

for $0 \leq t \leq 2s$

$$6t^2 - 12t = 6t(t-2) < 0$$

so $|\mathcal{E}| = 3(12t - 6t^2)$

Both at $t_1 = 0$ and $t_2 = 2s$ we get

$|\mathcal{E}| = 0$

To find the maximum we take the derivative of $|\mathcal{E}|$ with respect to t:

$$\frac{d|\mathcal{E}|}{dt} = 3(12 - 12t) = 0$$

$t_{max} = 1s$

$$|\mathcal{E}|_{max} = 3(12\cdot 1 - 6\cdot 1) = 18V$$

$$I_{max} = \frac{|\mathcal{E}|_{max}}{R} = \underline{6\,A}$$

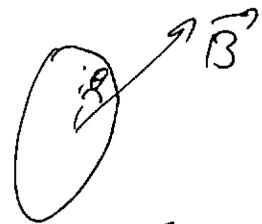
58. $N = 200$

$\Delta A = 39\,cm^2 = 39 \cdot 10^{-4}\,m^2$

$B = 50\,\mu T = 5 \cdot 10^{-5}\,T$

$\theta = 28°$

$\Delta t = 1.8\,s$



$$\Delta\phi = N B \Delta A \sin\theta = 1.83 \cdot 10^{-5}\,Wb$$

(note that θ is the angle between $\vec{B}$ and the plane of the coil, not the normal, hence sin instead of cos)

$$|\mathcal{E}| = \frac{|\Delta\phi|}{\Delta t} = \underline{1.02 \cdot 10^{-5}\,V}$$

12 $R = 6\,\Omega$

$\ell = 1.2\,m$

$B = 2.5\,T$

$I = 0.5\,A$

$\mathcal{E} = R \cdot I = 3\,V$

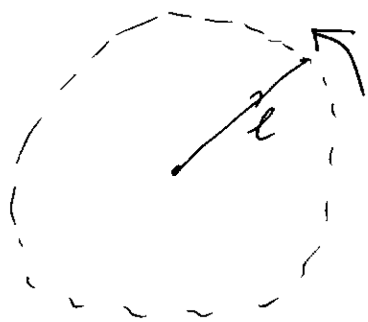
$\mathcal{E} = B \ell v$

$$v = \frac{\varepsilon}{B\ell} = \underline{1\,m/s}$$

$\underline{\underline{1g}}$ $\ell = 3\,m$

$f = 2\,rev/s$

$B = 50\,\mu T = 5 \cdot 10^{-5}\,T$



The blade covers an area of

$A = \pi \ell^2 = 28.3\,m^2$

in $T = \frac{1}{f} = 0.5\,s$

$\Delta\phi = A \cdot B = 1.41 \cdot 10^{-3}\,Wb$

$$|\varepsilon| = \frac{|\Delta\phi|}{T} = \underline{2.83 \cdot 10^{-3}\,V}$$

20. (a) The magnetic field towards right is decreasing, i.e. the change of flux is positive towards left, the induced current is directed clockwise when looking from the left to the loop, through R current goes to the right.

(b) After S is closed current flows counterclockwise through the coil when looking from the left, creating magnetic field to the left, by Lenz's rule the current in the loop (induced) will create an opposite magnetic field, i.e. to the right, so current flows in clockwise direction when looking from the left, the current through R is out of the page.

(c) Current I creates magnetic field into the page through the loop, and it is decreasing, so the induced current will create magnetic field into the page (Lentz's rule), so the current is clockwise, i.e to the right in R.

(d) The magnetic force on positive charges is upwards, so by right hand rule $\vec{B}$ points into the page.

23. $A = 0.1\ m^2$

$f = 60$ rev/s

$B = 0.2\ T$

$N = 1000$

$$\theta = \omega t = 2\pi f t$$

$$\phi = NAB\cos\theta = NAB\cos(2\pi f t)$$

$$\mathcal{E} = -\frac{d\phi}{dt} = NAB \cdot 2\pi f \sin(2\pi f t) =$$

$$= NAB\, 2\pi f \sin\theta$$

(a) $\mathcal{E} = \mathcal{E}_{max}$ when $\sin\theta = 1$

$\mathcal{E}_{max} = 7.54 \cdot 10^{3}\, V$

(b) $\sin\theta = 1$ when $\theta = 90°$ meaning the coil is parallel to $\vec{B}$ (θ is the angle between $\vec{B}$ and the normal to the coil)

25 $B = (0{,}03\, t^{2} + 1{,}4)\, T$

$R = 2.5\, cm = 0{,}025\, m$

$r_1 = 0{,}02\, m$

$t = 3s$

Imagine a ~~l~~loop with radius r_1

$A = \pi r_1^{2} = 1{,}26 \cdot 10^{-3}\, m^{2}$

$\phi = A B$

$\frac{d\phi}{dt} = A \frac{dB}{dt} = 1.26 \cdot 10^{-3} (0.06t)\, Wb$

$|\mathcal{E}|_{t=3s} = 2.26 \cdot 10^{-4}\, V$ counterclockwise

$E = \frac{|\mathcal{E}|}{2\pi r_1} = 1.8 \cdot 10^{-3}\, N/C$

in direction as shown: