Worked Solutions to Tutorial Sheet 4

1) Neglect Saturation.

With no current

ϕ per turn $= 0.625$ mWb

$\phi = BA = 0.625$ mWb

$$B = \frac{0.625 \times 10^{-3}}{2500 \times 10^{-6}} = 0.25T$$

When the coil is aiding the magnet, it needs to produce $1.6 - 0.25 = 1.35T$!

Total effective airgap seen by the coil

$$l_{geff} = 5 + 3 = 8mm$$

$$B = \frac{N I \mu_0}{l_{geff}} \implies I = \frac{l_{geff} B}{N \mu_0}$$

For $1.35T$, 100 turns, $\mu_0 = 4\pi \times 10^{-7}$

$$\underline{\underline{I = 8.6A}}$$

When opposing the magnet the coil needs to produce $1.85T$.

$$\implies \underline{\underline{I = 11.8A}}$$

(2).

At 20° : $L = \frac{\Delta\psi}{\Delta I} = \frac{0.4}{0.5} = 0.8H.$

At 60° $L = \frac{\Delta\psi}{\Delta I} = \frac{0.4}{0.5} = 0.8H.$

=

The torque produced by a machine is proportional to the rate of change of flux - linkage with rotor angle and not the absolute magnitude of flux - linkage

(a) 8000 rpm.

$\omega = \frac{8000 \times 2\pi}{60} = 837$ rads/s

Peak flux linkage on open circuit (ie $I=0$) is 1.18 Wb.

$\psi = 1.18 \sin\theta$

$\frac{d\psi}{d\theta} = 1.18 \cos\theta$

$\left.\frac{d\psi}{d\theta}\right|_{peak} = 1.18$ ← for $\cos\theta = 1$
i.e at $\theta = 0°$

$e_{peak} = \frac{d\psi}{d\theta} \cdot \frac{d\theta}{dt} = 1.18 \times 837$

$= 988V$

Since the emf is sinusoidal, $\text{rms} = \dfrac{988}{\sqrt{2}}$

$e_{rms} = 700V$

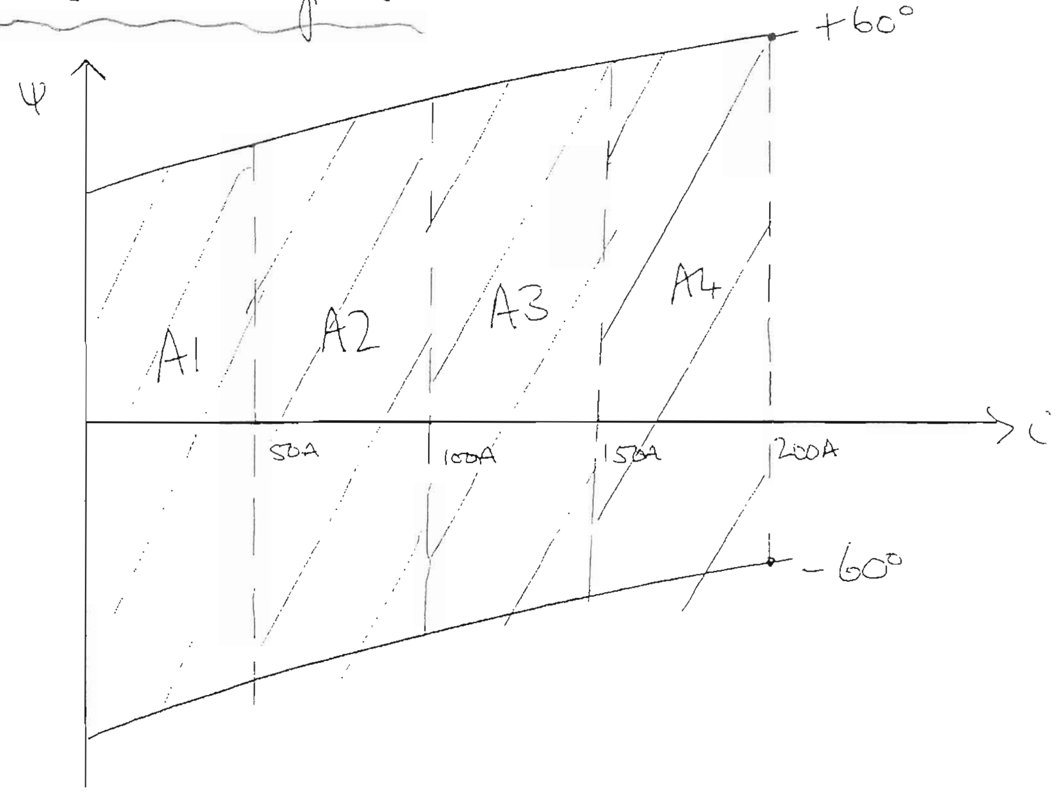
$=$

③ ⓐ 12 teeth (i.e $1\frac{1}{2}$ teeth per poles)

ⓑ At 90°, 200A.

$$L = \frac{\Delta\psi}{\Delta I} = \frac{0.02}{50} = 400\mu H.$$

ⓒ Plot ψ/i diagram



Calculate the areas A1, A2, A3 & A4 by applying simple trapezium integration

For 50A.

$$T = \frac{A1}{\underbrace{120 \times \frac{\pi}{180}}_{\text{convert to rads}}} \times pp = 4 \times 186$$

$$= 744\,Nm$$

For 200A.

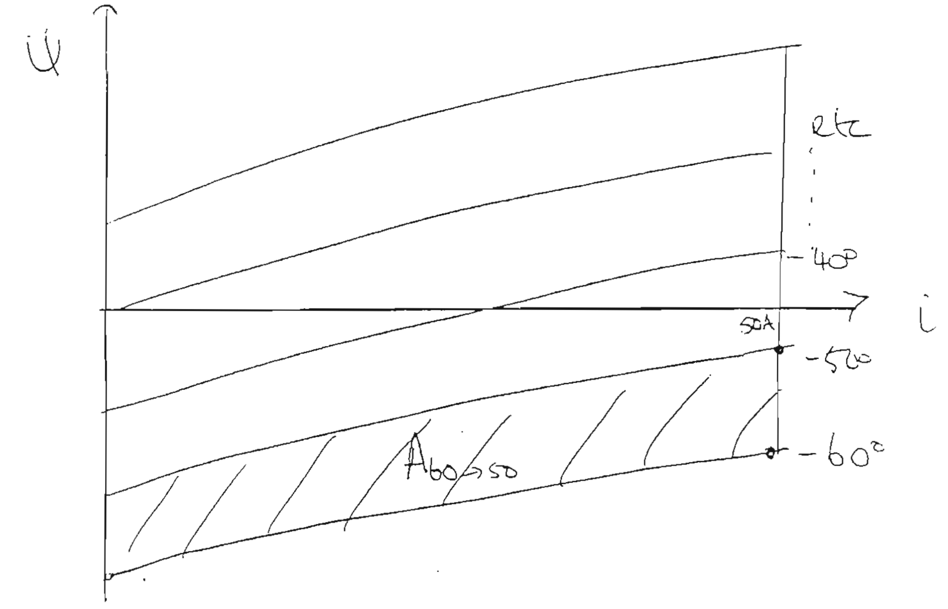
$$T = \frac{(A1 + A2 + A3 + A4)}{120 \times \frac{\pi}{180}} pp = 2852\,Nm$$

Repeat the same process for the $-80°$ to $+40°$ interval; values derived graphically are approximate

$$T_{50A} = 696\,Nm$$

$$T_{200A} = 2772\,Nm$$

3). Plot a ψ / i diagram.

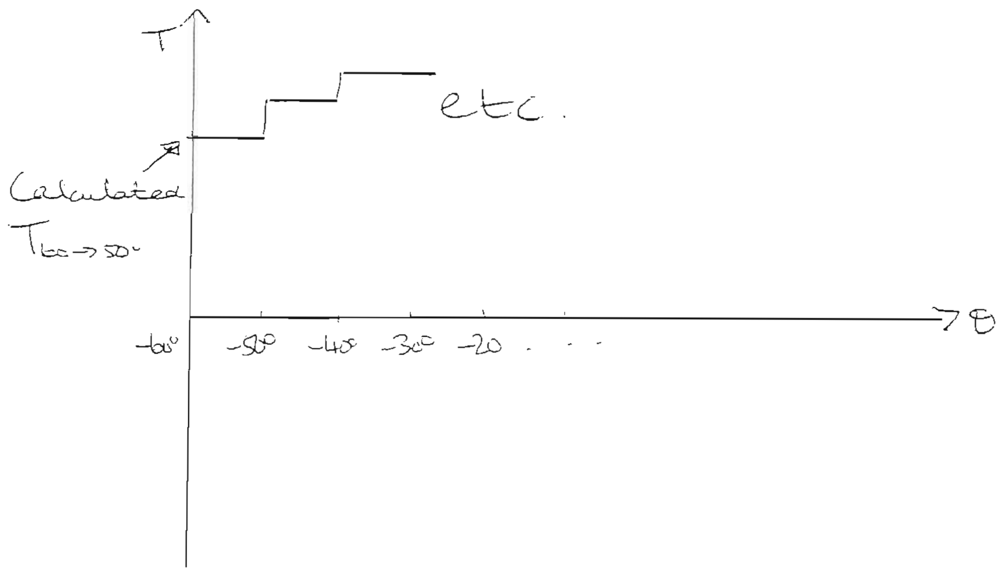


Calculate $A_{60 \to 50}$

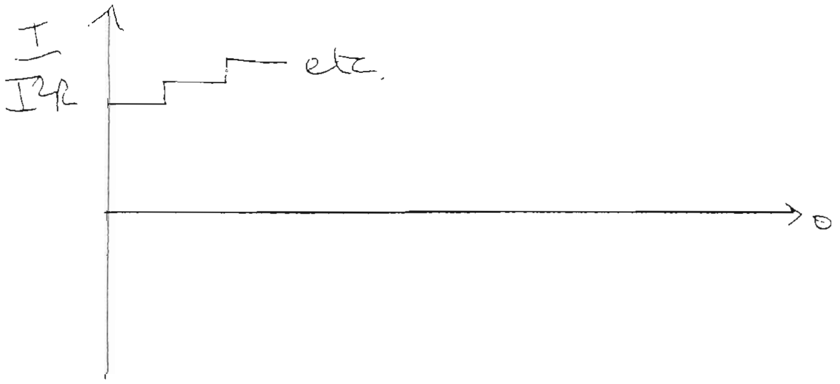
The average torque over this 10° interval is given by

$$T_{60 \to 50} = \frac{A_{60 \to 50}}{10 \times \frac{\pi}{180}} \times pp$$

Calculate for each interval and plot as a graph



(e). Plot same graph as before but divide by I^2R $(R = 1\Omega)$ (will give same shape, but demonstrates the variation in efficiency over the interval).



f) Supply with more sinusoidally shaped current

g) Max at 0°
Min at 90°

h) Higher torque per amp and hence efficiency.
Lower iron loss
Higher inductance → lower PWM frequency.

i) Aerospace, Motorsport
i.e any application where weight is more important than efficiency.