KING FAHD UNIVERSITY OF PETROLEUM & MINERALS

ELECTRICAL ENGINEERING DEPARTMENT

HW2: Magnetic Circuits

(1) A coil of 500 turns and resistance 20 Ω is wound uniformly on an iron ring of mean circumference of 50 cm and cross section 4 cm^2. It is connected to a 24-volt DC supply. Under these conditions, the relative permeability of iron is 800. Calculate the values of:

(a) the magnetomotive force
(b) the magnetic field intensity
(c) the total flux in the iron
(d) the reluctance of the ring

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(2) A square magnetic core has a mean path length of 55 cm and a cross-sectional area of 150 cm^2. A 200-turn coil of wire is wrapped around one leg of the core. The magnetization curve of the core material is shown in Fig. 1.

(a) How much current is required to produce 12 mWb of flux in the core?
(b) What is the relative permeability of the core at that level of current?
(c) What is its reluctance?
(d) Repeat part (a) if an air-gap of length 1 mm is cut across the core.
Assume a 5% increase in the effective air-gap area to account for fringing.

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(3) A cast-steel electromagnet shown in Fig. 2 has a coil of 1000 turns on its central limb. Calculate the current required to produce a flux of 2.5 mWb in the air-gap. Neglect magnetic leakage and fringing. Dimensions are given in cm. The magnetization curve of cast-steel is given as

B (Wb/m^2)	0.2	0.5	0.7	1.0	1.2
H (AT/m)	400	540	650	900	1150

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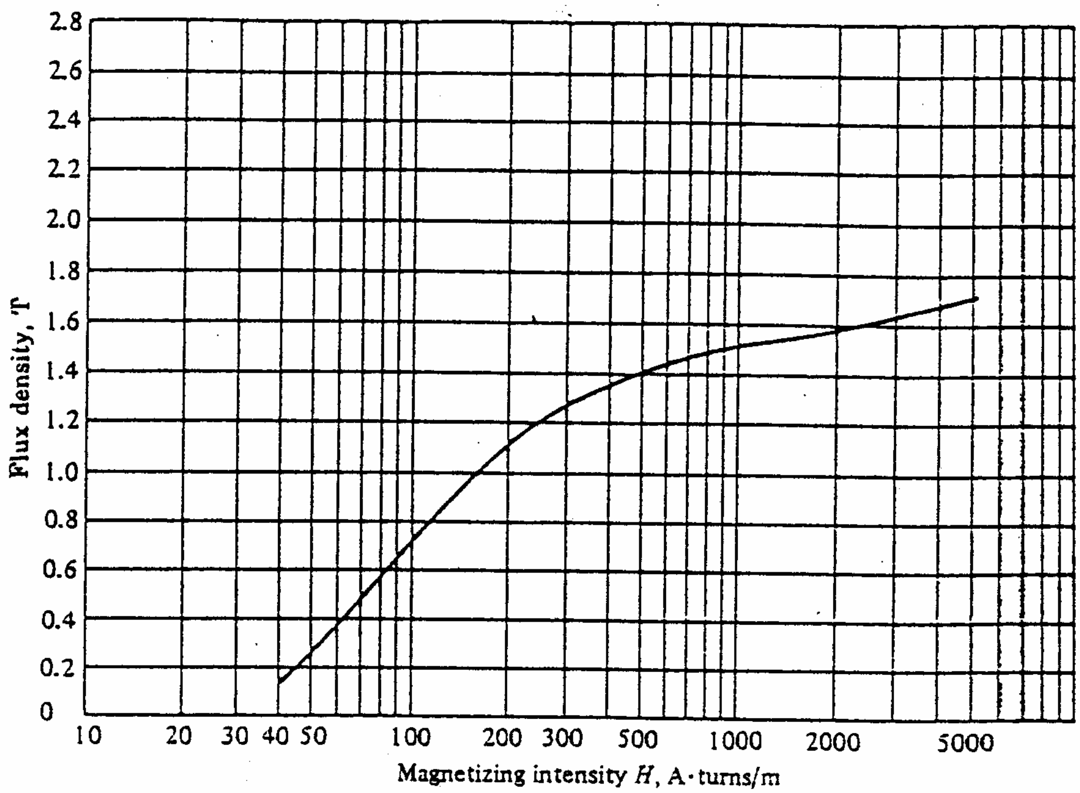
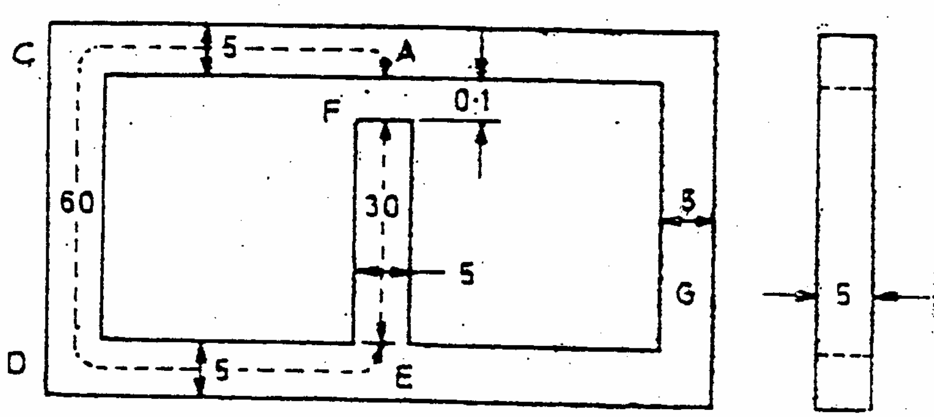
(4) The total core loss for a specimen of magnetic sheet steel is found to be 1800 W at 60 Hz. If the flux density is kept constant and the frequency of the supply increases 50%, the total core loss is found to be 3000 W. Compute the separate hysteresis and eddy-current losses at both frequencies.



Flux density, T
2.8
2.6
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0
10
20
30
40
50
100
200
300
500
1000
2000
5000
Magnetizing intensity H, A·turns/m

Fig. 1



C
5
A
0·1
F
60
30
5
5
G
5
D
5
E

Fig. 2

Problem #1

$$I = \frac{24}{20} = 1.2 \text{ A}$$

a) $F = NI = 1.2 * 500 = 600 \text{ AT}$

b) $H = \frac{F}{l} = \frac{600}{0.5} = 1200 \text{ AT/m}$

c) $B = \mu H = \mu_o \mu_r H = 4\pi * 10^{-7} * 800 * 1200 = 1.206 \text{ T}$

$\Phi = BA = 1.206 * 4 * 10^{-4} = 0.483 \text{ mWb}$

d) $\mathcal{R} = \frac{l}{\mu A} = \frac{0.5}{4\pi * 10^{-7} * 800 * 4 * 10^{-4}} = 1.243 * 10^{6} \text{ AT/Wb}$

Problem #2

$$B = \frac{\Phi}{A} = \frac{0.012}{0.015} = 0.8\ T$$

From the magnetization curve, the corresponding H

$$H \cong 115\ AT/m$$

Hence, $F = Hl = 115 * 0.55 = 63.25\ AT$

So,

a) $$I = \frac{F}{N} = \frac{63.25}{200} = 0.316\ A$$

b) $$\mu = \frac{B}{H} = \frac{0.8}{115} = 0.00696\ H/m$$

$$\mu_r = \frac{\mu}{\mu_0} = \frac{0.00696}{4\pi * 10^{-7}} = 5540$$

c) $$\mathcal{R} = \frac{F}{\Phi} = \frac{63.25}{0.012} = 5270\ AT/Wb$$

or, $$\mathcal{R} = \frac{l}{\mu A} = \frac{0.55}{5540 * 4\pi * 10^{-7} * 150 * 10^{-4}} = 5270\ AT/Wb$$

d) With the same flux $\Phi = 12\ mWb$, $B_c = 0.8\ T$

$H_c = 115\ AT/m$, $l_c = 0.55\ m$ (Neglect l_g; $l_g \ll l_c$)

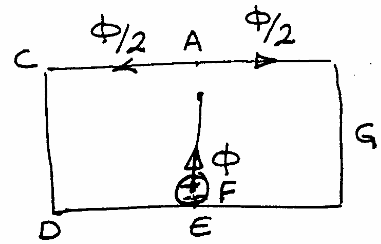
$$B_g = \frac{\Phi}{A_g} = \frac{0.012}{1.05 * 150 * 10^{-4}} = 0.762\ T$$

$$H_g = \frac{B_g}{\mu_0} = \frac{0.762}{4\pi * 10^{-7}} = 0.061 * 10^{7}\ AT/m, \quad F_g = H_g l_g$$

$$F_{total} = F_c + F_g = 63.25 + 0.061 * 10^{7} * 1 * 10^{-3} = 673.25$$

$$I = \frac{F_{tot}}{N} = \frac{673.25}{200} = 3.366\ A$$

Problem #3



Flux distribution as shown

$A = 5 * 5 = 25\ Cm^2$

$$B_g = \frac{2.5 * 10^{-3}}{25 * 10^{-4}} = 1.0\ T$$

$$* \quad H_g = \frac{B_g}{\mu_o} = \frac{1}{4\pi * 10^{-7}} = 79.58 * 10^{4}\ AT/m$$

$$, \quad l_g = 0.1\ Cm = 1 * 10^{-3}\ m$$

$* \quad B_{AE} = B_g = 1.0\ T$, the Corresponding $H_{AE} = 900\ AT/m$

$l_{AE} = 30\ Cm = 0.3\ m$

$* \quad B_{ACDE} = B_{AGE} = \frac{1}{2} B_{AE} = 0.5\ T$

The Corresponding $H_{ACDE} = H_{AGE} = 540\ AT/m$

$l_{ACDE} = l_{AGE} = 60\ Cm = 0.6\ m$

Hence;

$$F = H_g l_g + H_{AE} l_{AE} + H_{ACDE} l_{ACDE}$$

$$= 79.58 * 10^{4} * 1 * 10^{-3} + 900 * 0.3 + 540 * 0.6$$

$$= 1390\ AT$$

$$I = \frac{F}{N} = \frac{1390}{1000} = 1.39\ A$$

Problem # 5

For Constant B

$P_h \propto f$ i.e. $P_h = Af$ where A is Consta[nt]

$P_e \propto f^2$ i.e $P_e = Bf^2$ ~ B ~ ~

at 60 Hz

$$1800 = A * 60 + B * (60)^2 \longrightarrow (1)$$

at 90 Hz

$$3000 = A * 90 + B * (90)^2 \longrightarrow (2)$$

(1) by 3 and (2) by (2) and Subtract

$$3 * 1800 - 2 * 3000 = 3B * (60)^2 - 2B * (90)^2$$

$$-600 = -5400 B$$

So, $B = 0.111$ sub. in (1)

$A = 23.333$

Hence; At 60 Hz $P_h = 23.333 * 60 = 1400$ W

$P_e = 0.111 * (60)^2 \doteq 400$ W

At 90 Hz $P_h = 23.333 * 90 = 2100$ W

$P_e = 0.111 * (90)^2 = 900$ W