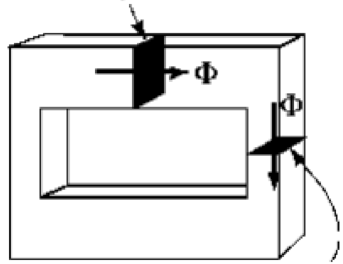
KING FAHD UNIVERSITY OF PETROLEUM & MINERALS
ELECTRICAL ENGINEERING DEPARTMENT

EE 306 – Term 191

HW # 2: Magnetic Circuits
Due Date: (Sep. 25th, 2019)
Key Solutions

Problem # 1:

For the magnetic core shown below, the flux density at cross section 1 is B_1 = 0.4 T. Determine B_2.



Solution:

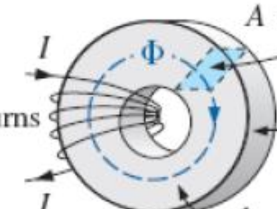
$$\boldsymbol{\Phi = B_1 \times A_1 = 0.8 \times 10^{-2} wb}$$

Since all flux is confined to the core, the flux at cross section 2 is the same as at cross section 1.

Therefore, $$\boldsymbol{B_2 = \frac{\Phi}{A_2} = 0.8\,T}$$

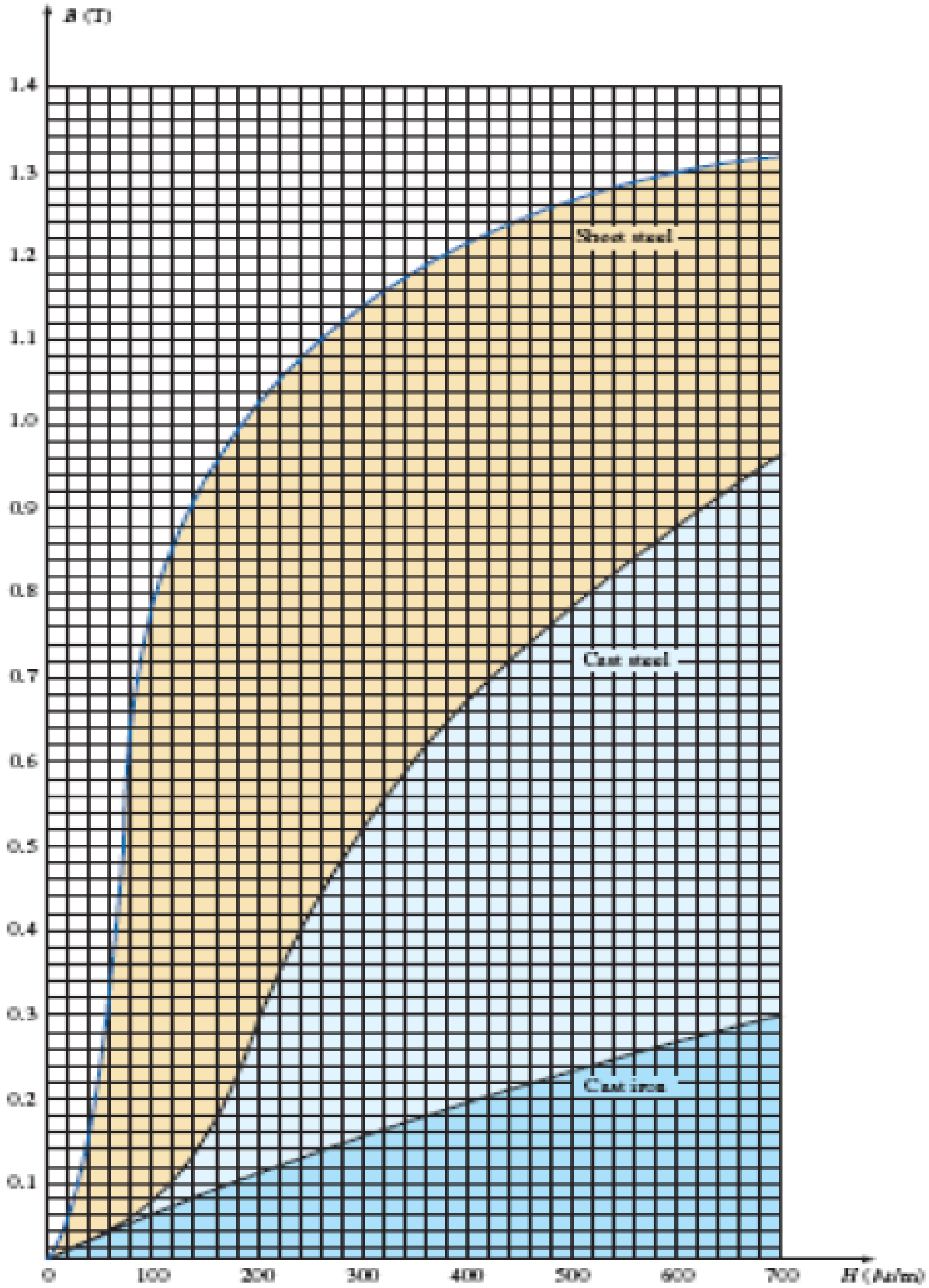
Problem # 2:

For the magnetic core shown below,



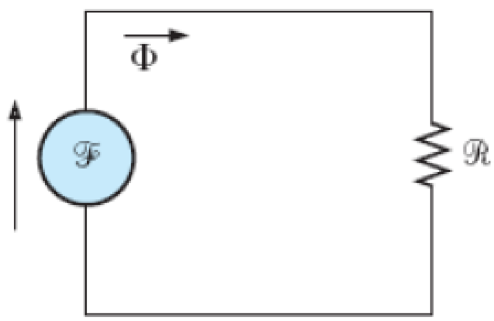
a. Find the value of I required to develop a magnetic flux of 4×10^{-4} Wb.

b. Determine μ and μ_r *for* the material under these conditions.



B (T)
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
100
200
300
400
500
600
700
H (At/m)
Sheet steel
Cast steel
Cast iron

Solution:



a. The flux density *B is*

$$B = \frac{\Phi}{A} = \frac{4 \times 10^{-4}\ \text{Wb}}{2 \times 10^{-3}\ \text{m}^2} = 2 \times 10^{-1}\ \text{T} = 0.2\ \text{T}$$

Using the *B-H curves, we can determine the magnetizing* force *H:*

$$H\ (\text{cast steel}) = 170\ \text{At/m}$$

Applying Ampère's circuital law yields

$$NI = Hl$$

$$I = \frac{Hl}{N} = \frac{(170\ \text{At/m})(0.16\ \text{m})}{400\ \text{t}} = \mathbf{68\ mA}$$

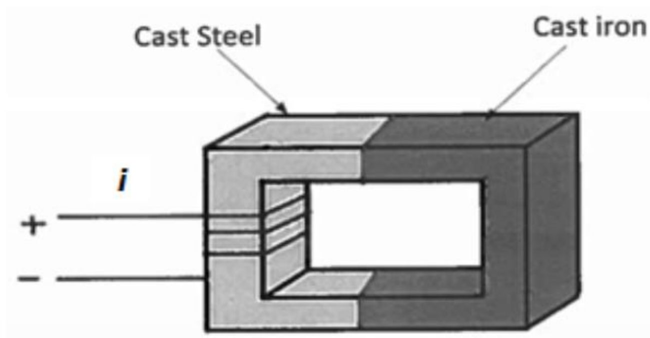
b. The permeability of the material

$$\mu = \frac{B}{H} = \frac{0.2\ \text{T}}{170\ \text{At/m}} = \mathbf{1.176 \times 10^{-3}\ Wb/A \cdot m} \qquad \mu_r = \frac{\mu}{\mu_o} = \frac{1.176 \times 10^{-3}}{4\pi \times 10^{-7}} = \mathbf{935.83}$$

Problem # 3:

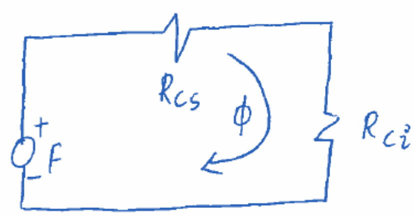
Consider a magnetic circuit as shown below. The core of the circuit is composed of cast steel and cast iron. Each material has a mean length of 20 cm. The cross section area of the core is 16 cm^2. The coil has 350 turns and it carries a current of 1.2 A. The relative permeability of the cast steel is 800 and that of cast iron is 250. Determine the following:

1) The flux in the core
2) The total flux linkage
3) The magnetic flux density B in the core



Solution

Magnetic equivalent Circuit



$$F = Ni = 350 \times 1.2 = 420$$

$$\boxed{F = 420 \text{ A.t}}$$

$$R_{cs} = \frac{l_{cs}}{\mu_{cs} A_{cs}} = \frac{20 \times 10^{-2}}{800 \times 4\pi \times 10^{-7} \times 16 \times 10^{-4}}$$

$$\boxed{R_{cs} = 124339.7 \text{ A.t/Wb}}$$

$$R_{ci} = \frac{l_{ci}}{\mu_{ci} A_{ci}} = \frac{20 \times 10^{-2}}{250 \times 4\pi \times 10^{-7} \times 16 \times 10^{-4}}$$

$$\boxed{R_{ci} = 397887.3 \text{ A.t/Wb}}$$

$$\Longrightarrow R_{eq} = R_{cs} + R_{ci}$$

$$R_{eq} = 522227.05 \text{ At/Wb}$$

$$F = Ni = \phi R_{eq}$$

$$\Rightarrow \phi = \frac{F}{R_{eq}} = \frac{420}{5222270.05}$$

1) $$\boxed{\phi = 8.042 \times 10^{-4} \text{ Wb}}$$

2) $$\lambda = N\phi = 350 \times 8.042 \times 10^{-4}$$

$$\boxed{\lambda = 0.2814 \text{ Wb.turn}}$$

3) $$B = \phi / A = \frac{8.042 \times 10^{-4}}{16 \times 10^{-4}}$$

$$\boxed{B = 0.502 T}$$

Problem # 4:

The core loss of a magnetic core is 2000 W at 50 Hz. Keeping the flux density constant, the frequency of the supply is raised to 75 Hz resulting in core loss of 3200 W. Compute separately hysteresis and eddy current losses at both the frequencies.

Solution:

For constant B_{max}

$W_h = Af$ and $W_e = Bf^2$

$W_t = W_h + W_e = Af + Bf^2$

at 50 Hz: $2000 = A \times 50 + B \times 50^2$ —— (1)

$3200 = A \times 75 + B \times 75^2$ —— (2)

solving 1 & 2 for A and B

$A = 34.667$ and $B = 0.10667$

at 50 Hz

$W_h =$ **1733.35 W**

$W_e =$ **266.65 W**

at 75 Hz

$W_h =$ **2600 W**

$W_e =$ **600 W**