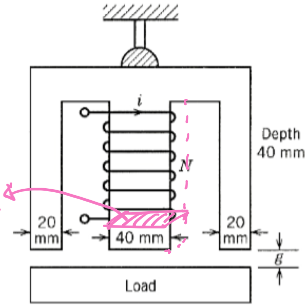
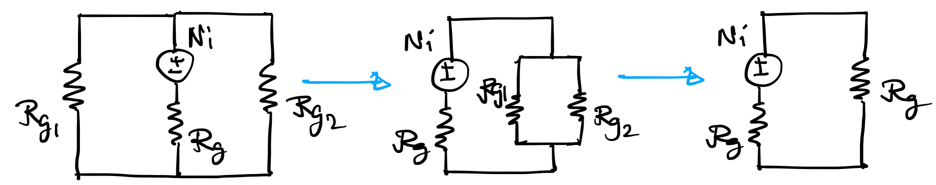


$A = 0.04 \times 0.04$

Equivalent ckt:

3 airgaps can be represented by 2 equivalent reluctances



$$R_g = \frac{l_g}{\mu_0 A_g}, \quad R_{g1} = R_{g2} = \frac{l_g}{\mu_0 \frac{A_g}{2}} = 2 \cdot \frac{l_g}{\mu_0 A_g}$$

$$R_{g1} \parallel R_{g2} = \frac{2 \cdot \frac{l_g}{\mu_0 A_g}}{2} = \frac{l_g}{\mu_0 A_g} = R_g$$

For airgap,

Length, $l_g = 10\text{ mm} = 0.01\text{ m}$

width $= 40\text{ mm} = 0.04\text{ m}$

depth $= 40\text{ mm} = 0.04\text{ m}$

cross section area, $A_g = 0.04 \times 0.04 = 0.0016\text{ m}^2$

a(i) Determine coil current, i :

mmf, $\mathcal{F} = Ni = H_g l_g$

for 2 airgaps in equivalent ckt

$$\therefore \quad i = \frac{H_g l_g}{N} = \frac{\frac{B_g}{\mu_0} \cdot l_g}{N} = \frac{\frac{1.25}{4\pi \times 10^{-7}} \times (2 \times 0.01)}{2500} = \boxed{7.9577\text{ A}}$$

a(ii) Determine energy stored in magnetic system, W_f :

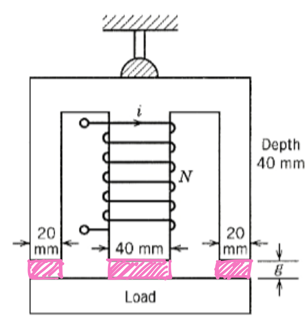
For magnetically linear system (as the core is ideal),

$$W_f = \frac{1}{2} L i^2 = \frac{1}{2} \lambda i = \frac{1}{2} N \varphi i = \frac{1}{2} N (B_g A_g) i$$

$$\therefore \quad W_f = \frac{1}{2} \times 2500 \times 1.25 \times 0.0016 \times 7.9577 = \boxed{19.89425\text{ J}}$$

Alternative solution :

$$W_f = \frac{1}{2} L i^2$$
$$= \frac{1}{2} N \varphi i$$
$$= \frac{1}{2} (Ni) \varphi$$
$$= \frac{1}{2} \left(\frac{B_g}{\mu_0} \cdot l_g \right) \varphi$$
$$= \frac{1}{2} \left(\frac{B_g}{\mu_0} \cdot l_g \right) (B_g A_g)$$
$$= \frac{1}{2} \cdot \frac{B_g^2 (l_g A_g)}{\mu_0}$$
$$= \frac{B_g^2 V_g}{2 \mu_0}$$
$$= \frac{(1.25)^2 \times (0.08 \times 0.04 \times 0.01)}{2 \times 4\pi \times 10^{-7}} = \boxed{19.89425\text{ J}}$$



Total volume of air-gap,

$$V_g = \underbrace{(0.02 + 0.04 + 0.02)}_{\text{width}} \times \underbrace{0.04}_{\text{depth}} \times \underbrace{0.01}_{\text{length}}$$

$$= 0.08 \times 0.04 \times 0.01\ \text{m}^3$$

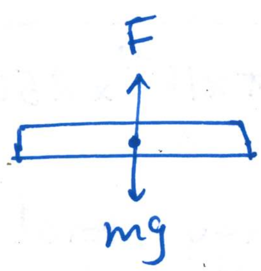
iii) Determine force on the load, F.

Work done on load is energy in magnetic system

$$W_f = \underbrace{F \times d}_{\text{force} \times \text{distance}} \Rightarrow F = \frac{W_f}{d} = \frac{19.89425}{0.01} = \boxed{1989.425\,N}$$

iv) Determine the mass of the load, m.

Assuming that the load (steel sheet) now sticks to the two prongs (i.e. NO ACCELERATION) the following FBD (free body diagram) is valid -



$F = mg$

$$\Rightarrow m = \frac{F}{g} = \frac{1989.425}{9.81} = \boxed{202.8\,kg}$$

b) If air gap, $g = 2mm$, what is the current in the coil?

Force, F, required to lift the load is the same. New work done/energy is-

$W = F \times g = 1989.425 \times 0.002 = 3.9789\,J$

Assuming flux density stays constant $\Rightarrow$ flux linkage unchanged

$$\Rightarrow \frac{1}{2}Li^2 = W = \frac{1}{2}\frac{\lambda}{i}i^2 = \frac{1}{2}.NBA.i \Rightarrow i = \frac{2W}{NBA} = \frac{2 \times 3.9789}{2500 \times 1.25 \times (2 \times 0.02 \times 0.04)}$$

$$\Rightarrow \boxed{i = 1.5916\,A}$$

Q2 Given

$N = 400$ turns, $R = 5\Omega$, $R_c \approx 0$

$A = 5cm \times 5cm = 25 cm^2 = 0.0025 m^2$

air gp, $g = 1mm = 0.001 m$, Avg. force on load, $F = \underline{550N}$

a) For the DC supply

i) Determine DC voltage, V_{dc}

$V_{dc} = i \cdot R \longrightarrow$ Find i!

Work needed to be done on load = energy in magnetic system

$\Rightarrow W_f = F \times d = 550 \times 0.001 = \underline{0.55 J}$

Assuming a magnetically linear system (you can do this because the question doesn't explicitly state otherwise)

$$W_f = \frac{1}{2} L i^2$$, but what is L?

if the reluctance of the core is negligible, then the reluctance of the path comes only from the air gaps.

$$\Rightarrow R_{path} = 2R_g = \frac{2 \cdot l_g}{\mu_0 A_g} = \frac{2 \times 0.001}{4\pi \times 10^{-7} \times 0.0025} = 636619.77 \ \frac{\text{A turns}}{\text{Wb}}$$

$$\Rightarrow L = \frac{N^2}{R_{path}} = \frac{400^2}{636619.77} = \underline{0.2513H}$$

So $i = \sqrt{\frac{2W_f}{L}} = \sqrt{\frac{2 \times 0.55}{0.2513}} = \underline{\underline{2.092\ A}}$

$\therefore V_{dc} = iR = 2.092 \times 5 = \boxed{\underline{\underline{10.46V}}}$

ii) Determine energy stored in the magnetic field.

$W_f = F \times d = 550 \times 0.001 = \boxed{\underline{\underline{0.55J}}}$

b) Using an AC supply, determine the AC voltage.

To apply the same force, we need the RMS AC current to be the same as the DC current $\Rightarrow \underline{i_{rms} = 2.092A}$

Now $V_{rms} = i_{rms} \times Z$, what is Z?

$Z = \sqrt{R^2 + X_L^2} = \sqrt{R^2 + (2\pi \times 60 \times L)^2}$

$= \sqrt{5^2 + (2\pi \times 60 \times 0.2513)^2} = \underline{94.87\Omega}$

$\therefore V_{rms} = 2.092 \times 94.87$

$\Rightarrow \boxed{\underline{\underline{V_{rms} = 198.47V}}}$