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Part 1A Paper 3: Electrical and Information Engineering,
ELECTROMAGNETICS

EXAMPLES PAPER 2 Electromagnetics

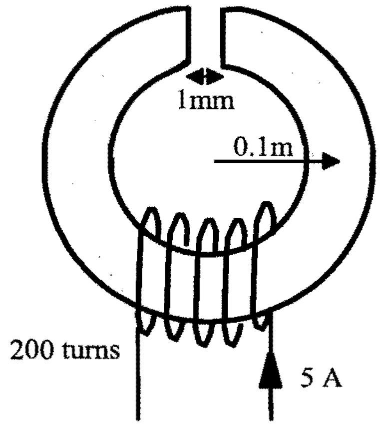
*Straightforward questions are marked with a + and more difficult questions are marked with a *.*

1⁺. A 400 turn coil is wound on a toroidal iron core with average radius R = 5 cm, cross sectional radius r = 2.5 cm and relative permeability μ_r = 800. What will be the magnetic flux density B produced within the toroid by a current of 0.5 A ? What is the corresponding magnetic flux ϕ?

2. A soft iron toroidal ring has a mean radius of 0.1 m and a uniform cross sectional area of 500 mm^2. A 200 turn coil is wound around the toroid and carries a current of 5 A. An air gap of 1 mm is cut in the toroid, Fig.1 . The *B-H* relation for the iron is given in the table below. Neglect fringing effects. Find the magnetic flux density B in the air gap. If the current is reduced linearly to zero in 1 ms what voltage is developed across the ends of the winding?

H Am^{-1}	50	100	150	200	300	500	800	1,500
B Tesla	0.1	0.3	0.55	0.73	0.95	1.2	1.4	1.5

Fig.1



3*. A magnetic pickup is shown in Fig 2. Calculate the current required to produce a magnetic flux density of 0.1T in the air gap if L_g = 1mm, L_m = 50mm, N = 100 turns and the electro magnet is filled with a linear magnetic material with a relative permeability of 250. State any approximations made. Comment briefly on what might happen if i) the current were doubled, ii) the current were increased by a factor of 20.

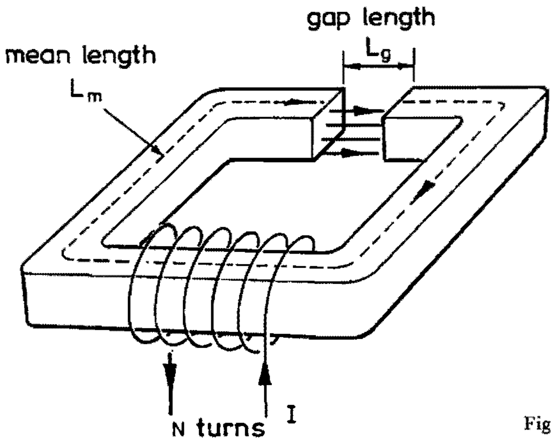
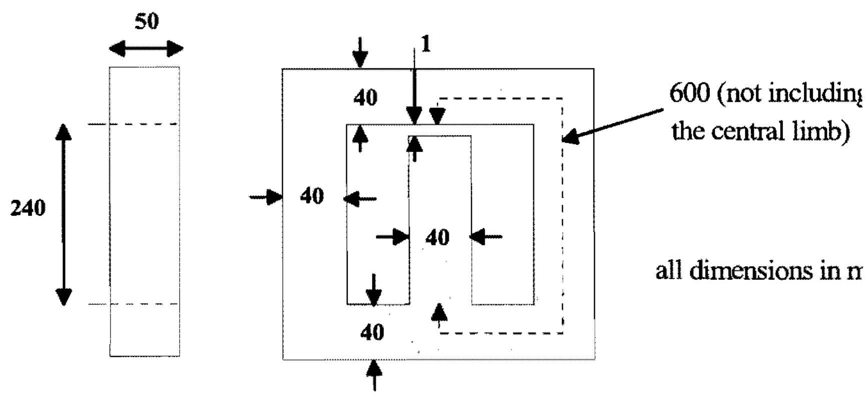


Fig 2

4. A 680 turn coil is wound on the central limb of the 4% silicon-iron core shown in Fig.3 . A total flux of 2.4×10^{-3} Wb is required in the air gap. Neglecting leakage and fringing calculate the necessary coil current. If the coil on the centre limb were replaced by two equal coils, one on each outer limb with their flux reinforcing each other in the air gap, calculate the Ampère-turns required in each coil to produce the same flux as above.

Fig.3

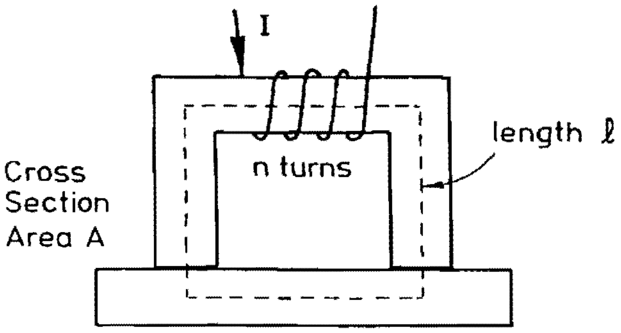


5*. Consider the electromagnet in Fig 4 which has a soft iron core and is holding up a soft iron bar. It is wound with N turns of wire carrying a dc current I. The length around the magnetic circuit is l. The cross sectional area is A throughout and the relative permeability of the soft iron is μ_r. Derive an expression for the magnetic flux density B in the core of the electromagnet. State any assumptions made.

Use the method of virtual work to calculate the total attractive force acting on the bar. State any approximations made. Evaluate the force for l = *100mm*, N = *80*, μ_r = *1000*, I = *0.5A* and A = $3x10^{-5}\ m^2$. [Hint. The magnetostatic energy per unit volume is the area under the B-H curve]

Fig 4

$$W = \int_0^B H.dB$$



Answers

1. 0.64 T, 1.26×10^{-3} Wb
2. 1.0 T, 100 V
3. 0.95A, 0.2T
4. 1.55A, 1057 Amp turns
5. $W = \dfrac{B^2}{2\mu_0}$ (per m^3), 0.5T, 6N

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