Ampere's Law, etc.

Text 30.3 - 30.5

- Ampere's Law examples
- Magnetic Flux and Gauss's Law for magnetism

Practice: Chapter 30,
Objective Questions 1, 12, 14
Problems 34, 43, 47, 48

Ampère's Law

$$\oint \mathbf{B} \cdot \mathbf{ds} = \mu_{\mathrm{o}} I_{\mathrm{encircled}}$$

Exercise:
What does the law mean, in words? what are you integrating over?

Calculating **B** from Ampere's Law

For a few simple shapes, we can calculate the field B easily from Ampere's Law. The steps:

i) use symmetry to deduce the general behaviour

ii) pick a closed curve on which to apply Ampere's Law, taking advantage of the symmetry

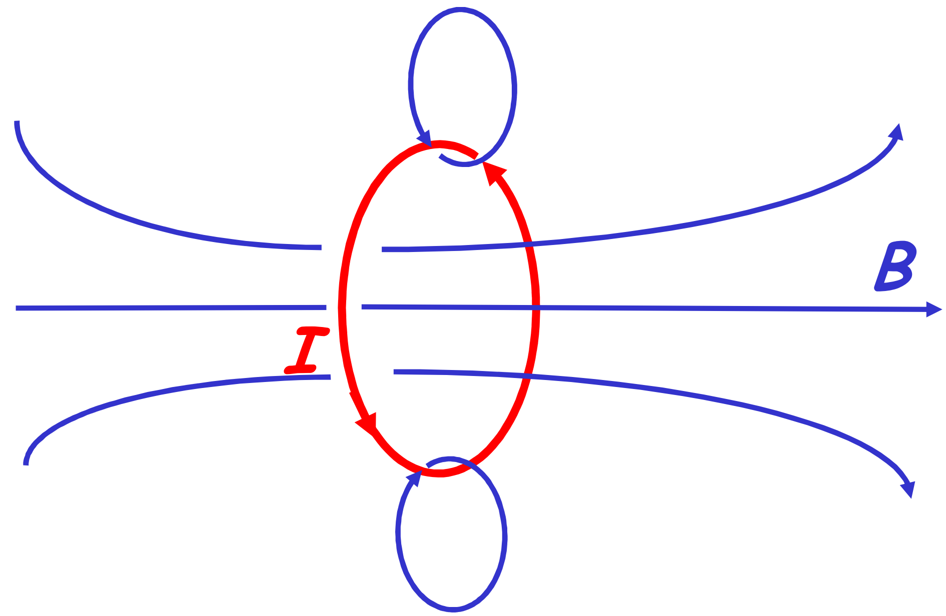
iii) Calculate $\oint \mathbf{B} \cdot \mathbf{ds}$ (in terms of $|\mathbf{B}|$)

iv) Calculate $I_{encircled}$

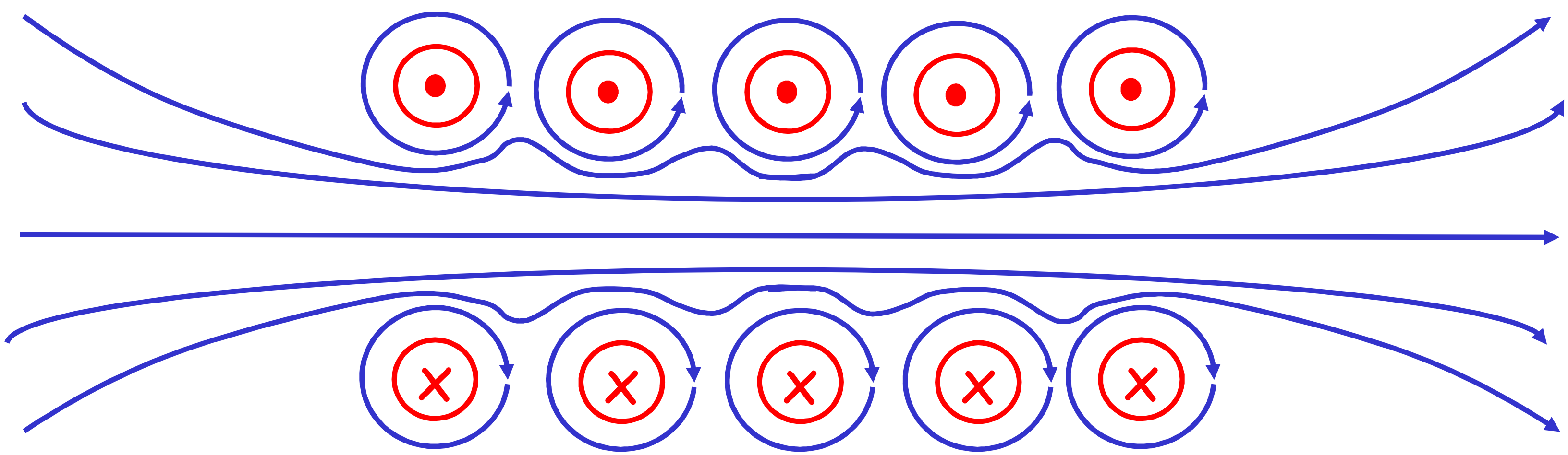
v) Apply Ampere's Law to get B

Field patterns for circular coils

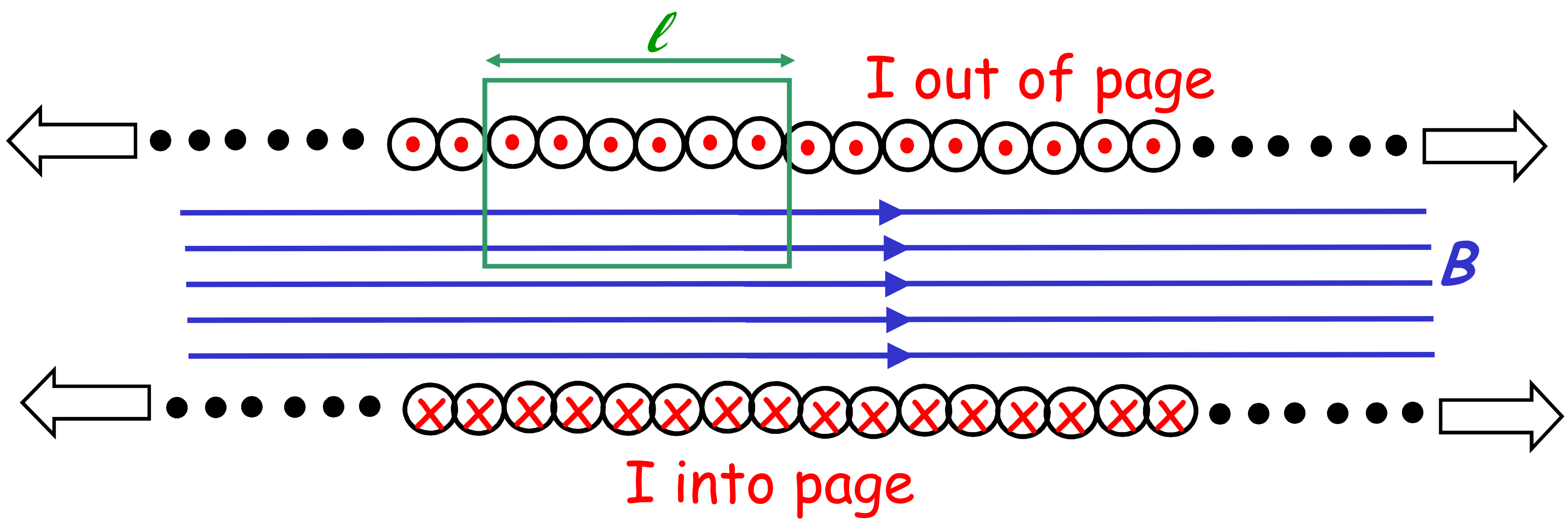
Single Coil:



Several Coils:



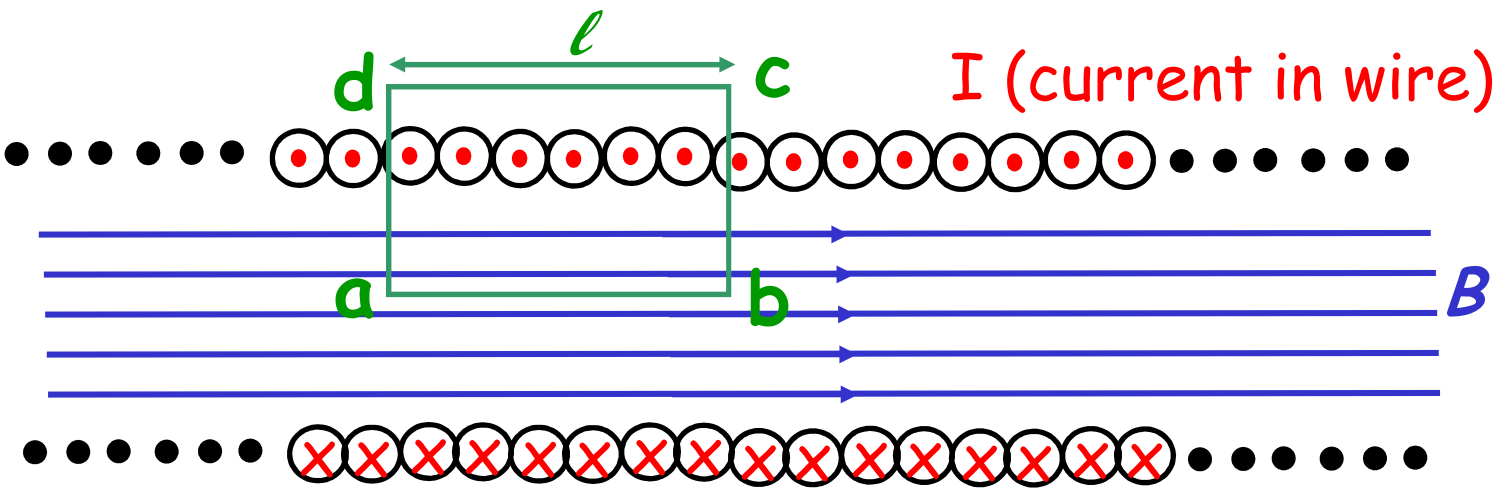
Solenoid (long straight coil)



Outside: $B \approx 0$

Inside: B *is uniform, parallel to solenoid axis*

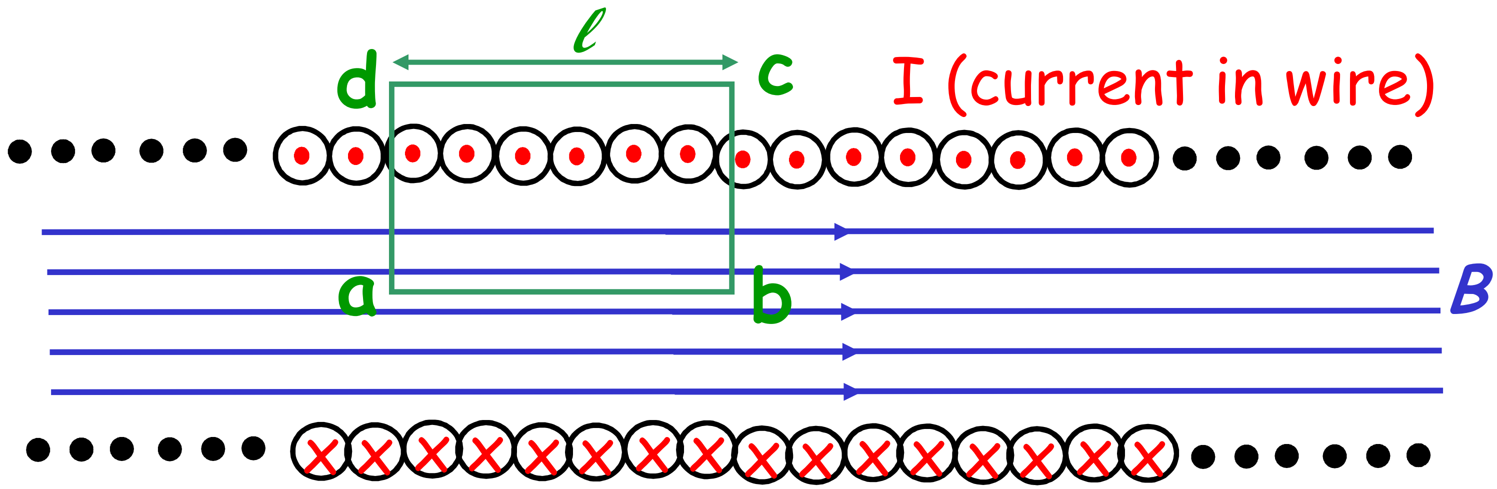
Quiz



On which sides of the green rectangle is $\int \mathbf{B} \cdot d\mathbf{s}$ *not* zero?

A) bc and ad only
B) ab only
C) cd only
D) ab, bc, and ad only

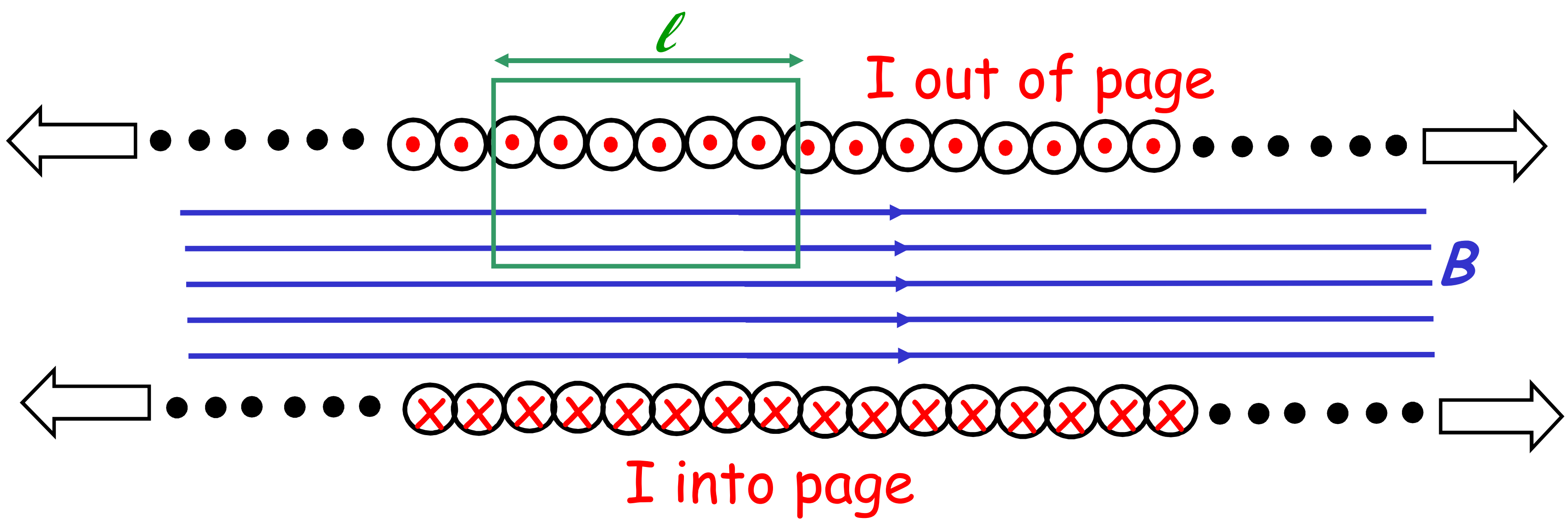
Quiz



The "current encircled" by the green rectangle shown is

A) equal to I
B) equal to 6I
C) equal to zero

Solenoid (long straight coil)



Outside: $B \approx 0$

Inside: $B = \mu_0 n I$ *(uniform, parallel to solenoid axis)*

where n = number of turns per metre of length

Example: Solenoid 20 cm long, 2000 turns, I = 1 amp

Then n = 100 turns/cm (1×10^4 turns/m)

$$\Rightarrow B = \mu_o n I = 4\pi \times 10^{-3}\ \mathrm{T}$$

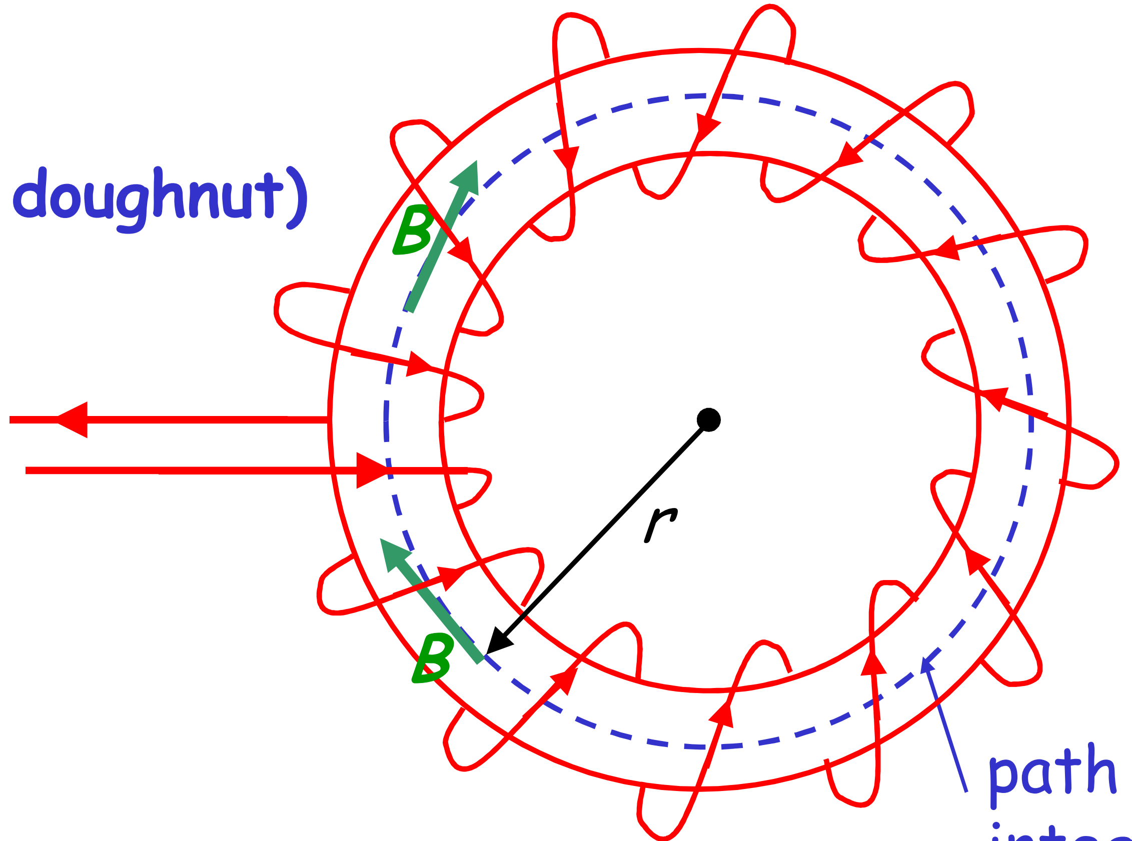
$$= 0.013\ \mathrm{T}\ (130\ \text{gauss})$$

Quiz: What would the field be if we had half as many turns, on a solenoid half as long?

A) 32.5 gauss
B) 65 gauss
C) 130 gauss
D) 260 gauss
E) 520 gauss

Toroid

(coil on a doughnut)

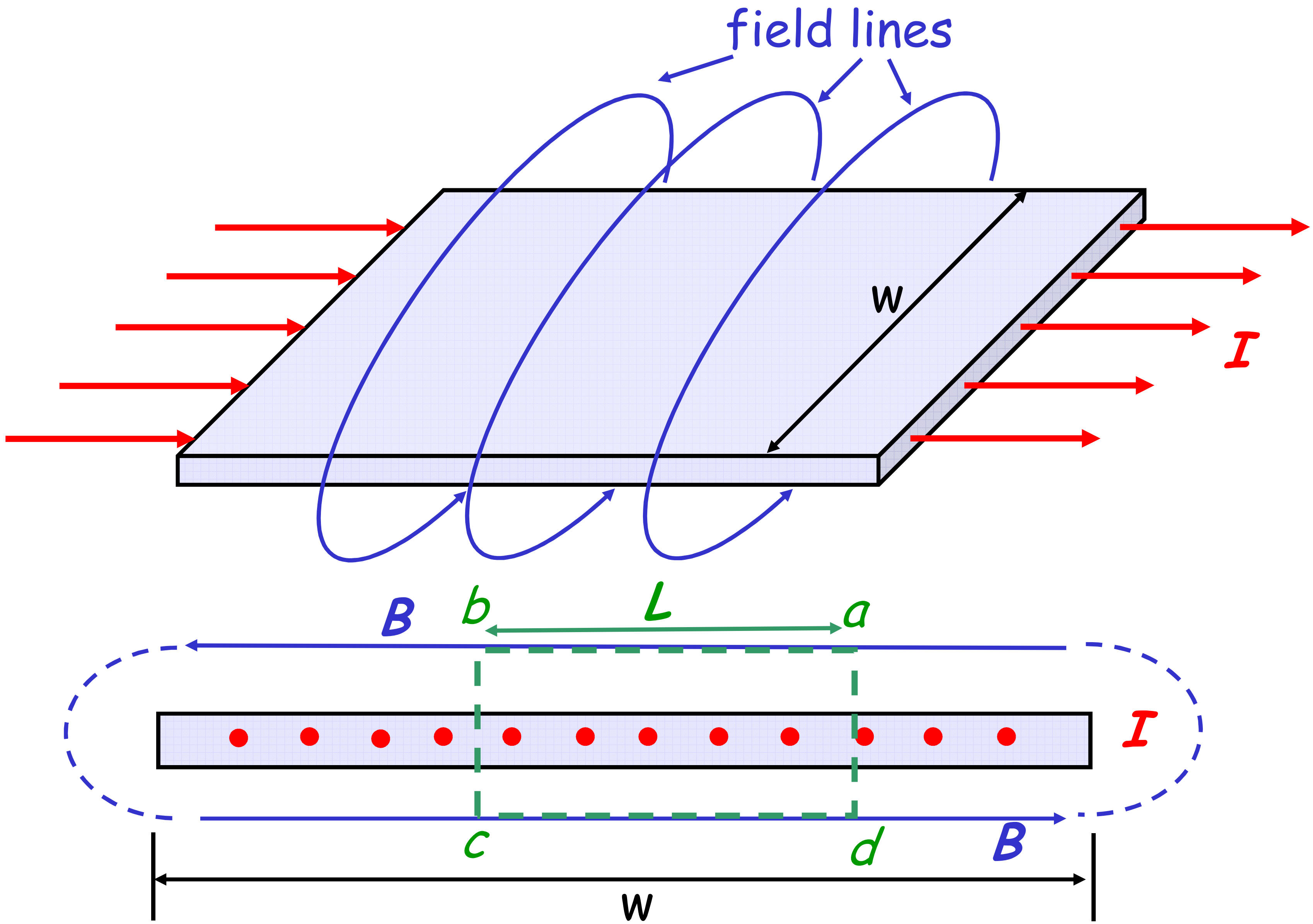


Show that, inside the toroid,

$$B = \frac{\mu_o NI}{2\pi r}$$

(N = total number of turns)

Thin Sheet of Current (e.g. in a strip of foil)



Homework Exercise:

Apply Ampere's Law to the rectangle abcda, and show that

$$B = \frac{\mu_o I}{2w}$$

Limitations: this is valid for points not too far from the sheet, and not too close to the edge (compared to the width *w*).

Magnetic Flux

(this has no connection to Ampère's law)

Flux through a surface *S*:

$$\Phi_B = \int_S \mathbf{B} \cdot \mathbf{dA}$$

($\mathbf{dA}$ *is the "area vector", perpendicular to the surface.)*

- a *scalar* ; units, $1\ T \cdot m^2 = 1$ weber (Wb)
- represents *"number of field lines through S"*

Gauss's Law for Magnetism

The magnetic flux through any closed surface is zero.

This is equivalent to:

- the field lines form closed loops

- there are no isolated magnetic poles

("magnetic monopoles")