Toroidal Solenoid

Midterm 2

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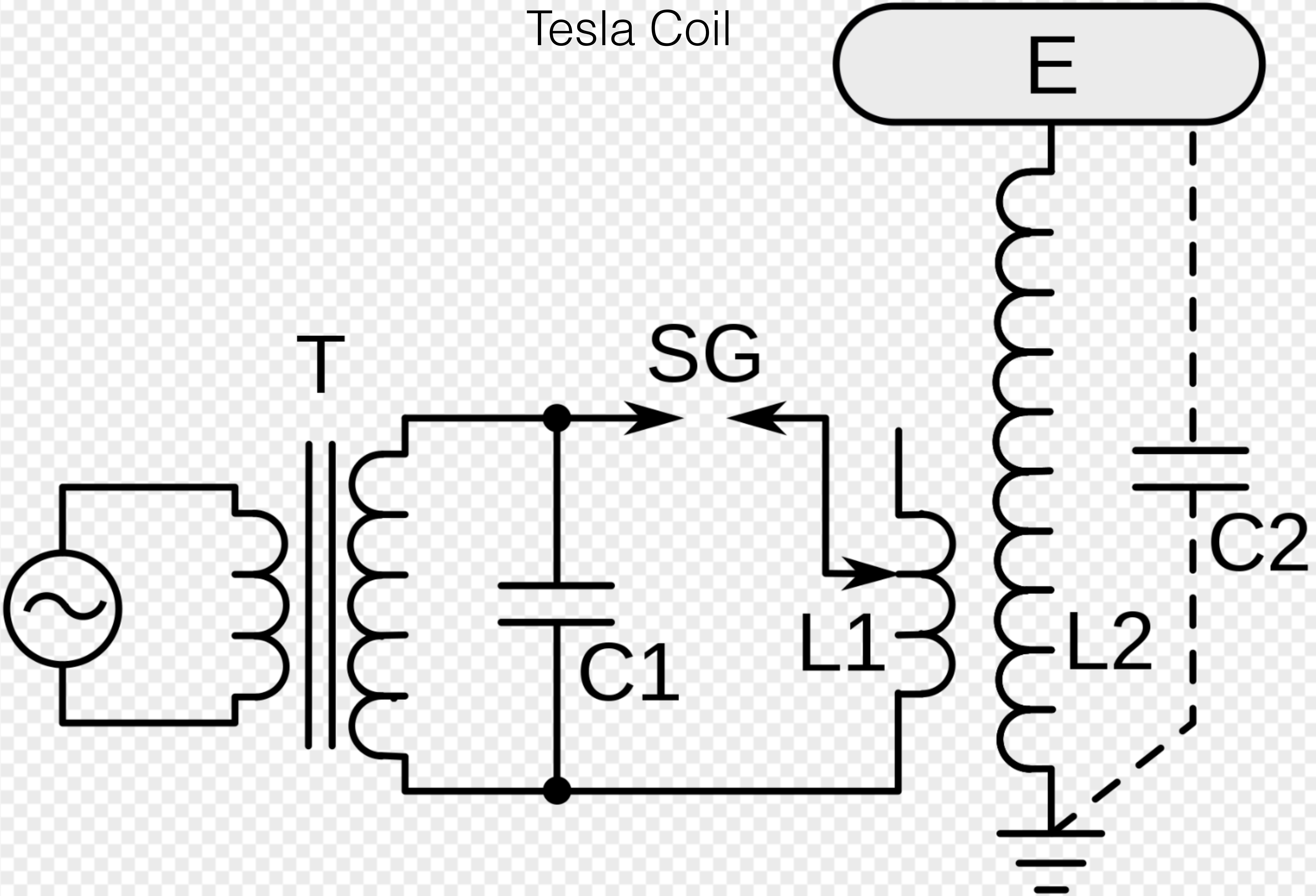
Friday July 5: 6:30 to 8:00, Room B9201

Covers material up to Last Friday's lecture

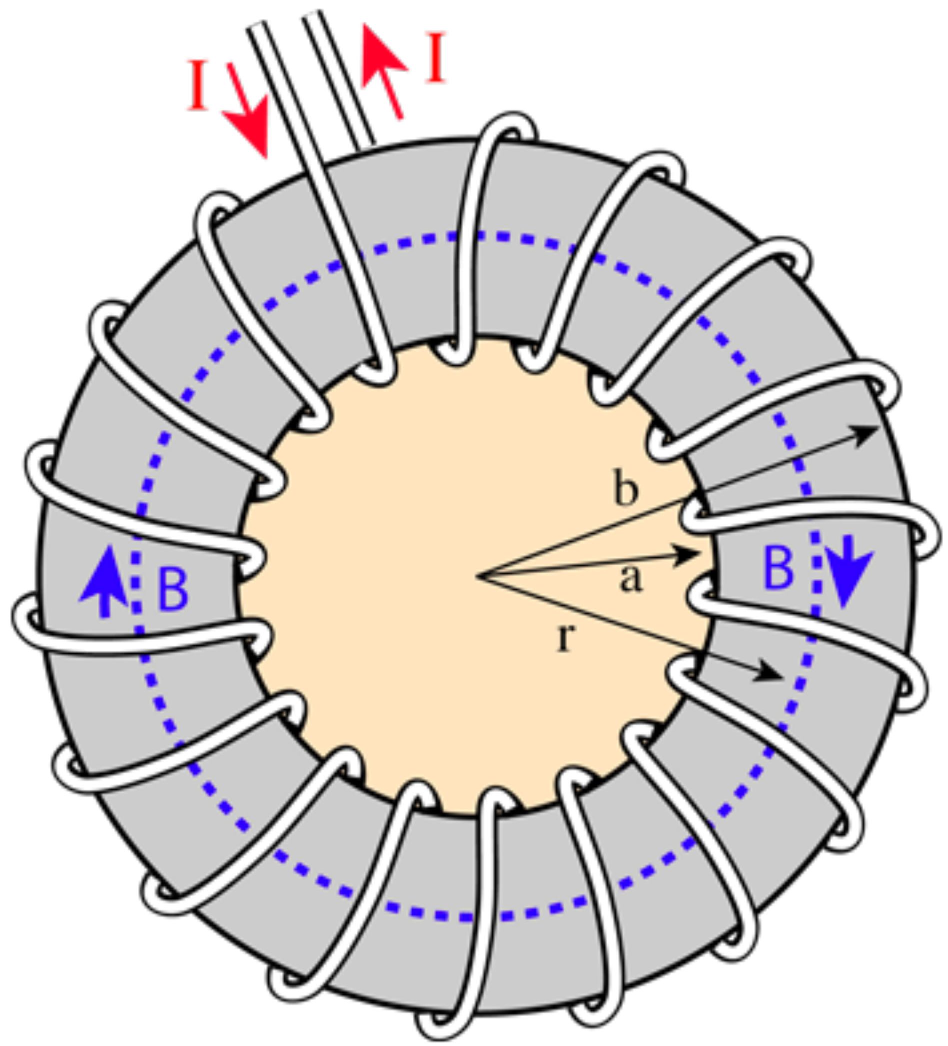
Emphasis on stuff from Kirchhoff's Rules to Induction

Bring your student ID.

Tesla Coil



Unipolar Tesla coil circuit. C2 is not an actual capacitor but represents the parasitic capacitance of the secondary windings L2, plus the capacitance to ground of the toroid electrode E.



$$\mu_0 I_{encl} = \oint \vec{B} \cdot d\vec{\ell}$$

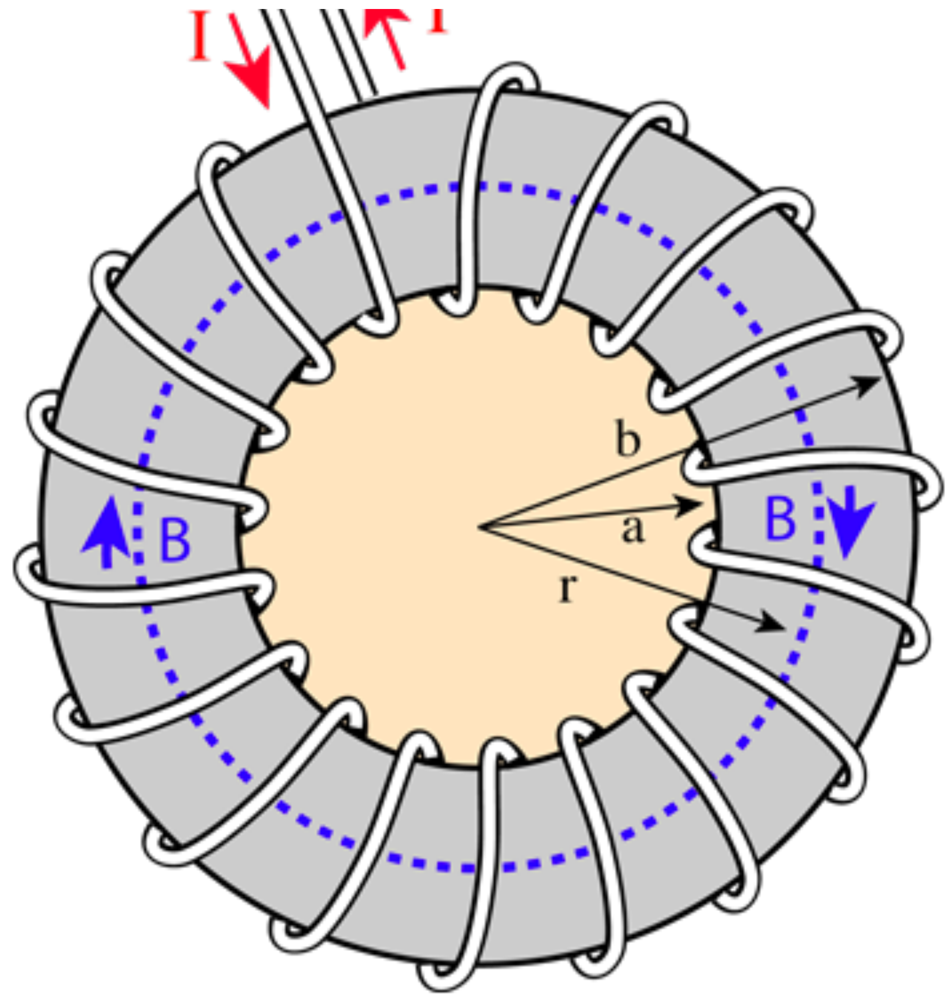
I_{encl} = NI = Number of loops x current in the wire

B is constant in magnitude and tangent to the dotted amperian loop.

by symmetry

Numerical Example

r = 6 cm
a = 5 cm
b = 7 cm
I = 1 A
N = 100



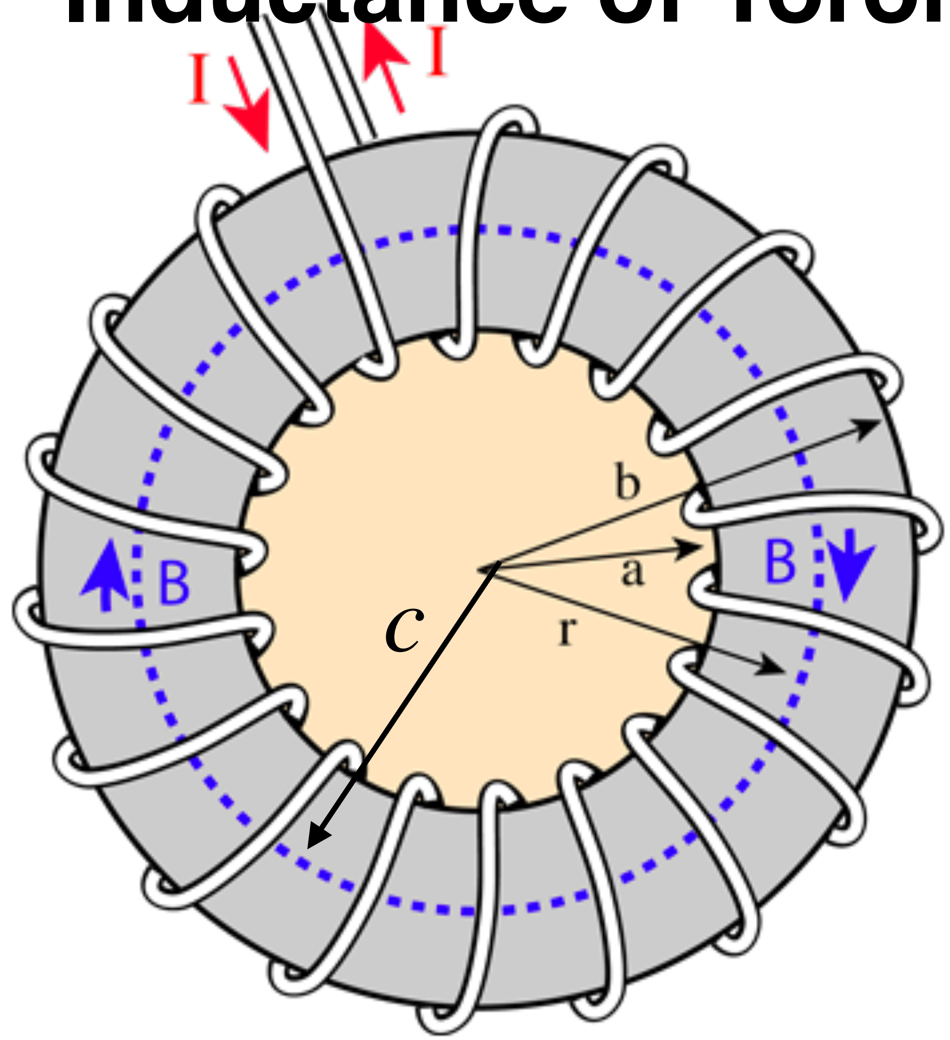
N loops

at radius r = 6 cm:

$$B = \frac{\mu_0 N I}{2\pi r} = \frac{(4\pi \times 10^{-7})(100)(1)}{2\pi(6 \times 10^{-2})} = 0.000333 \text{ T}$$

at radius **a:** B = 0.000400 T
at radius **b:** B = 0.000286 T

Inductance of Toroid



N loops

$$B = \frac{\mu_0 N I}{2\pi r}$$

Multiply by NA
and divide by I

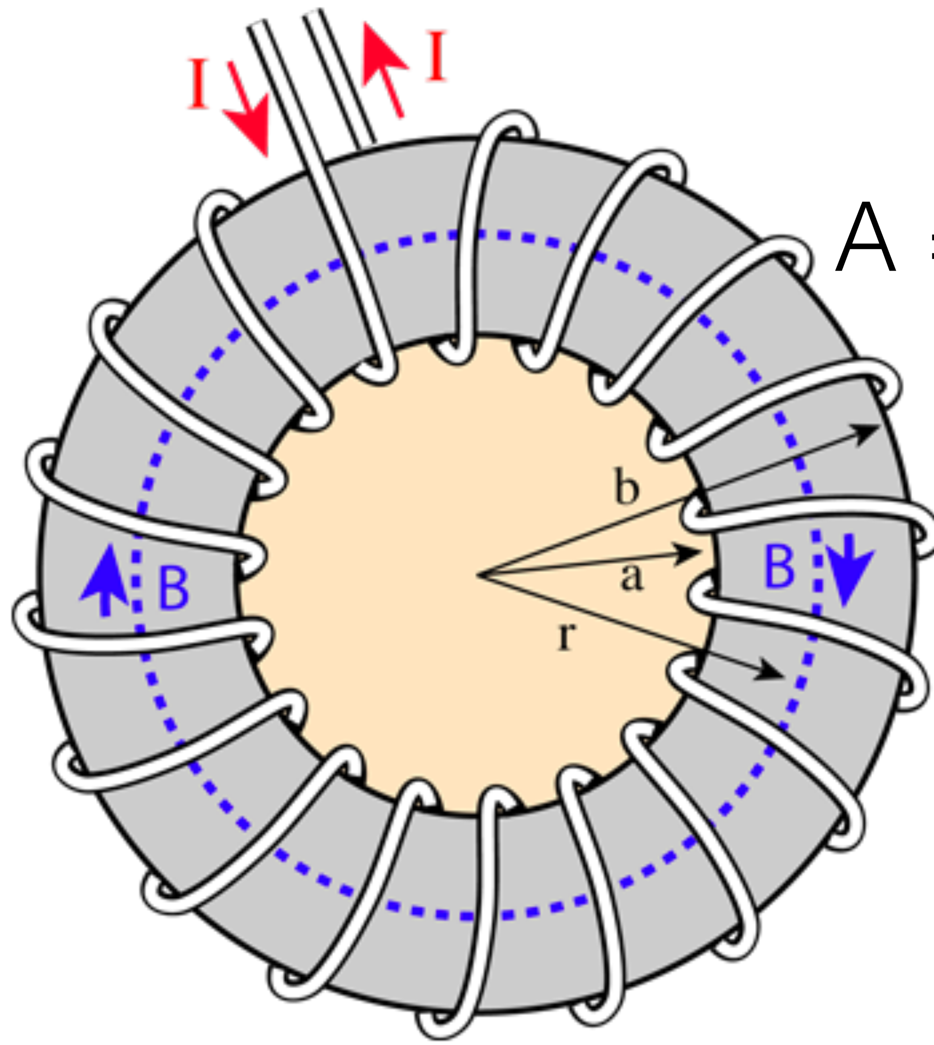
$$L \approx B\frac{NA}{I} = \frac{\mu_0 N I}{2\pi r}\frac{NA}{I} = \frac{\mu_0 N^2 A}{2\pi r}$$

A = cross-sectional area

r = toroid radius to centerline

Design Problem:

Air-core toroidal inductor with an inductance of 1 mH.



r = 6 cm

b–a = 2 cm

A = π cm² =0.000314 m²

$$L \approx \frac{\mu_0 N^2 A}{2\pi r}$$

$$N \approx \sqrt{\frac{2\pi L r}{\mu_0 A}}$$

=977 turns

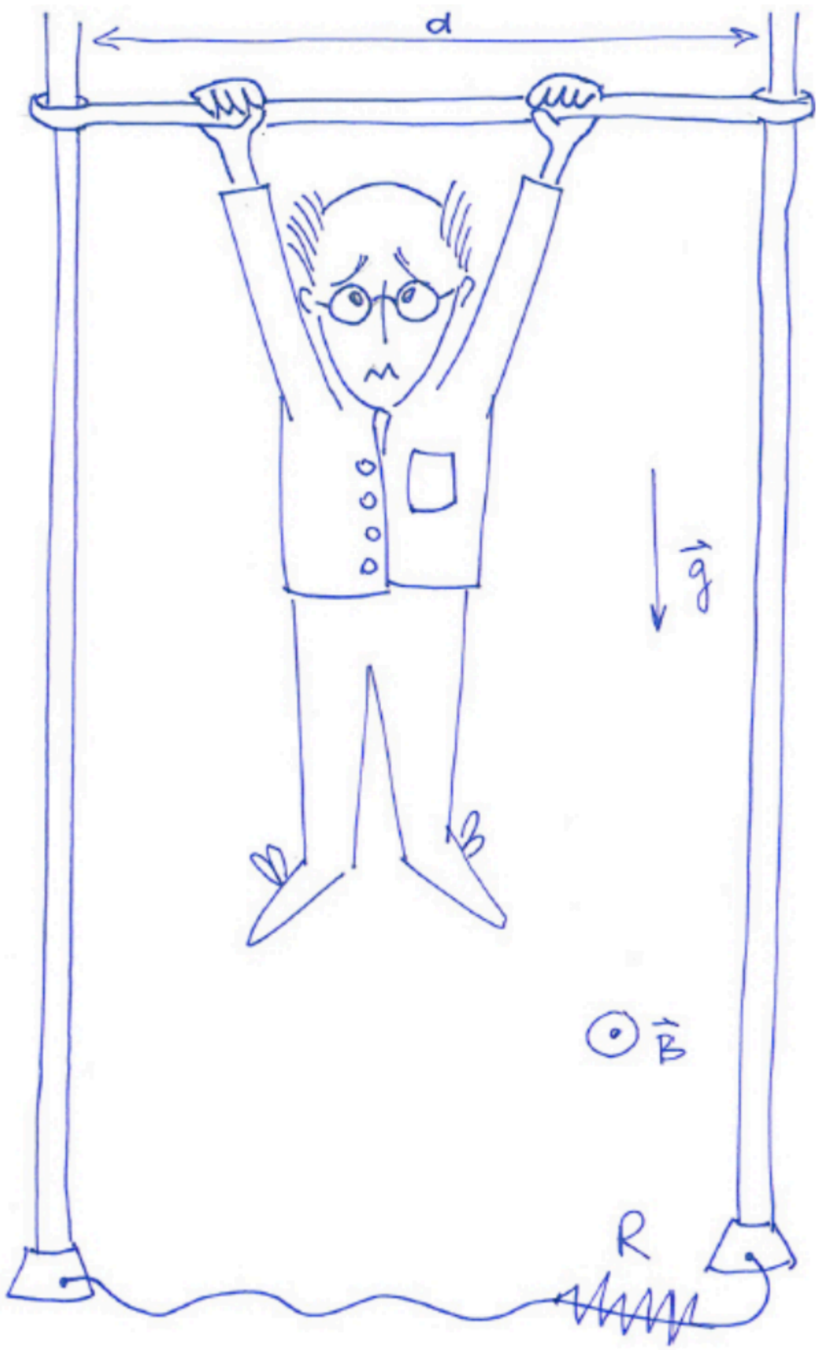
Too many turns!

Solution: high μ core such as ferrite

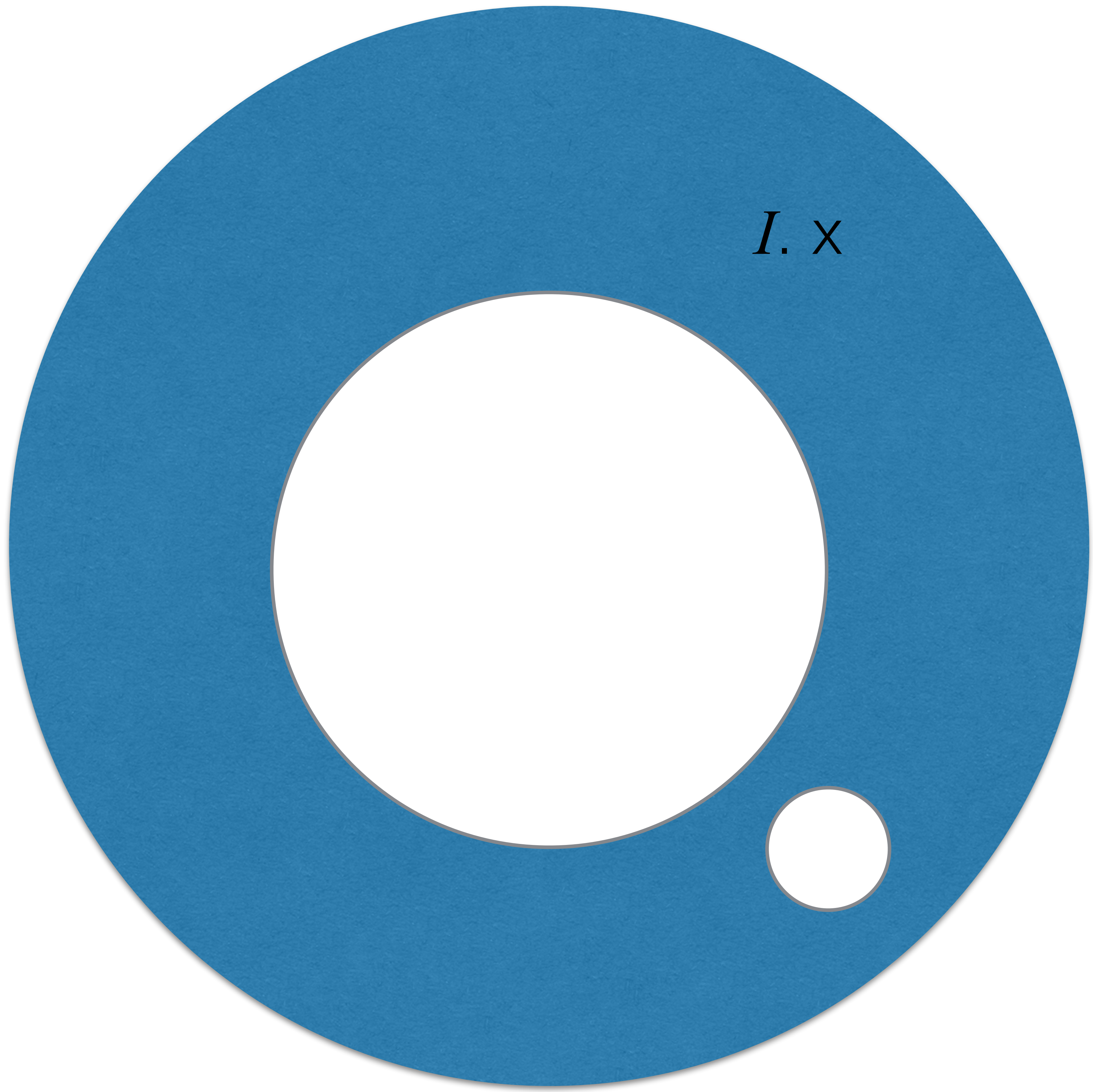
https://www.mag-inc.com/Products/Ferrite-Cores

Magnetic Parachute [edit]

A physics professor is demonstrating the concept of a “magnetic parachute” using the construction shown in the picture below. The poles and the bar are made of a conducting material that has a negligible resistance, and form a closed loop with a constant resistance R=100 Ohm. The distance between the poles is d=2m. The professor starts from a position that is sufficiently high to reach a constant terminal velocity. The room is filled with a uniform magnetic field $\vec{B}$ pointing out of the page, as shown. Suppose the professor weighs 80 kg. How strong should the magnetic field be in order for the terminal velocity to be within the safe landing range of $v_t <$ 8m/s?



L. Pogosian, 2018



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