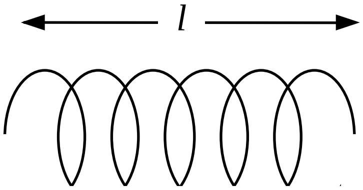
Discussion Question 10B
Physics 212 Week 10
Inductors

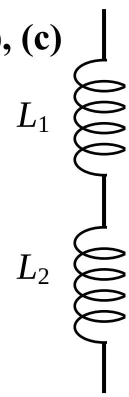
In this question, we will explore the effective inductance of series and parallel combinations of wire coils. In your calculations, you can assume that your coils are all very long compared to the radii of their circular turns … which allows you to approximate them as infinite solenoids.

(a)

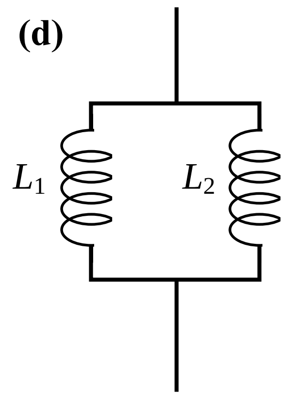


n turns per meter
coil area A

(b), (c)



(d)



(a) Calculate the self-inductance L of the coil in figure (a).

The formula is $L = \Phi/I$ … just remember, the magnetic flux Φ we're talking about here is that caused by the coil's *own* field, not some external field as in earlier problems. (That's what we mean by *self*-inductance). So run some current I through the coil and see what flux it causes.

(b) Work out the equivalent inductance for two inductors in series. Write down a relationship between the voltage and current through the *pair* of inductors, in terms of L_1 and L_2 for each coil. This relation should show that the pair of inductors is equivalent to a *single* coil with inductance L_s.

Let V be the voltage across the pair, and let V_1 and V_2 be the voltages across the individual inductors. Start with an equation relating these …

(c) What about two coils connected in *parallel*? Using the technique from part (b), determine the effective inductance L_p of this new combination.

(d) Finally, here's a little design challenge, to help you develop some intuition about how inductors are constructed. Suppose you have a spool of thin wire of total length D = 5 m and radius R = 0.2 mm. You can make an inductor out of this wire by wrapping it into tight circular turns, thereby forming a spiral. How should you do the wrapping to achieve the maximum possible inductance? Given that you will make circular turns, there are only two parameters you can vary: the radius r of your turns, and the gap g between them (i.e. how tightly you pack your turns.) Let's try three designs and see which one gives the greatest self-inductance L.

(i) Design #1: Use circular turns of radius r = 1 cm, and pack them as tightly as possible without causing any of the turns to overlap.

(ii) Design #2: Double the turn radius r to 2 cm.

(iii) Design #3: Go back to the 1 cm turn radius, but this time try packing the turns more loosely: leave a gap of 1 wire diameter between each turn.

Hint- write L in terms of the winding radius r, the total wire length D, and the spacing between the wire centers.