Physics Assignment 7

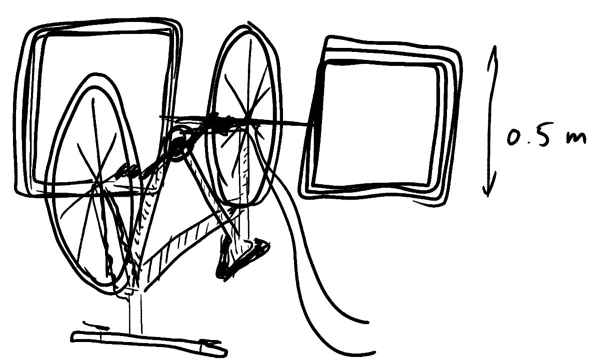
One afternoon, a bunch of Science One students are just chillin'[1] in 361 when they notice, tucked away in the corner, a large pile of thick, 0 gauge copper wire, a small 1W light bulb, and a note attached to the bulb that says "Lumos!" The students begin to speculate on this unusual development, wondering what it all could mean. Everyone has their own theory, but the one thing that they agree upon is that surely something wonderful will happen if they manage to light the bulb. Giddy with anticipation, the students scour the room looking for a battery so that they can connect it to the bulb using the copper wire and see what happens next. To their great dismay, the students quickly realize that IKBL 361 is fresh out of batteries. "Harumph!" exclaims one of the students. "Harumph!" echo the other students in disappointment. As a last resort, some of the students try waving various wand-like objects at the bulb shouting "Lumos!," but this achieves nothing but a disapproving stare from Lucia.

The students slump back into their chairs, trying to think of some other idea for how to light the bulb, but it has been a long day, and they are fresh out of ideas. Just when they are about to give up completely, the students become aware of a rustling sound coming from the pile of copper wire. Looking over, they spot a small shimmering creature, human in form but no larger than a pretzel[2], working its way out from under a medium sized coil. Having liberated itself, the creature springs into the air and hovers in front of the students with a tiny pair of wings. "Gadzooks!" exclaims one of the students in surprise and amazement. "Gadzooks!" echo the other students, bewilderedly.[3] An awkward silence ensues. "Um…who are you?" one of the students asks, finally.

[1] This is a lie. They aren't really just chillin'. They are actually working on a math assignment. However, for the purposes of this question, let's pretend that they're just chillin'.
[2] The big soft kind that they sell at the mall, not the little crunchy kind.
[3] This is actually a word.

“*I* am the Induction Fairy! In your hour of need, when all hope is lost, if induction can save you, I appear!” exclaims the Induction Fairy. The students would have been be more impressed had the Induction Fairy sounded less like a chipmunk, but they are intrigued nonetheless. “Do you mean induction as in math induction or physics … oh, never mind,” says one of the students, just then remembering the giant pile of copper wire and the light bulb. By this point, some of the students are starting to clue in that induction might indeed be the solution to their problems. “Maybe we could build a coil of wire and spin it around near a big magnet,” suggests a student. “If the coil were connected to the light bulb, that would induce a current and light the bulb,” finishes another. “But where are we going to find a big magnet?” asks a third, strongly suspecting that room 361 might be fresh out of big magnets. “You’re standing on one!” exclaims the Induction Fairy dramatically, spreading his arms as if to suddenly reveal the Earth around them. “Well, my work is done here. Goodbye!” he says, flying off though the cries of “Thanks Induction Fairy!”

Forty-five minutes later, the students have rigged up the following setup, with two 200 turn square coils of wire attached to the back wheel of an upside-down bicycle.



By turning the pedals on the bicycle, a student can get the coils spinning 4 times per second.

Question 1: Supposing the bike is oriented to face directly towards magnetic north, determine the EMF as a function of time and the maximum EMF. Assume the Earth's field in the room to be 0.5 Gauss.

Question 2: Taking into account the resistance in the wire and the 12 Ohm resistance of the bulb, will the students be able to light up the 1W bulb with their setup? If not, supposing that they use additional bicycles and coils and connect them together in series, and figuring on one students per bicycle and one to coordinate everyone, *how many Science One students does it take to light a lightbulb?*

Question 3: For a single bicycle, the students turning the pedals are able to generate 100Nm of torque on the back wheel and coil up until the final angular speed is reached. If the net moment of inertia of the wire and wheel is 0.3 kg m^2, and if the wheel starts from rest, what is the EMF as a function of time during the time that period?

Question 4: Suppose that the two loose wires from the coil are connected together to close the circuit (without the lightbulb). Determine the torque on the system due to magnetic forces when the wheel is spinning at 4 revolutions per second.

Question 5: Starting from rest and assuming a constant torque as in question 3, estimate how much longer it would take to spin up the wheel to 4 revolutions per second with the circuit closed compared with the circuit open.

Question 6 (optional): What happens when the students light the bulb?

Question 7: A current I flows in a wire with radius R. Using Ampere's Law, determine the magnetic field at a distance $r < R$ from the middle of the wire (*Hint: how much current is going through the part of the wire inside radius r?*). *See the notes for Wednesday's class for examples.*