Your name: ____________________ **TA name: _____________________**

Written HW 4: Magnetic Accelerators
(due Thurs, Oct 14, 2010 at 5 PM)

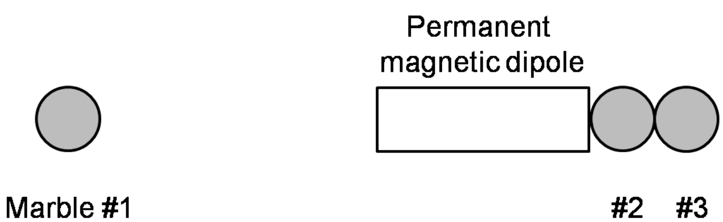
Turn in this written homework in the appropriate slot in the brown Homework Cabinet at the entrance of the HelpRoom, Duane G2B90. Please STAPLE pages together, and **put your name and TA name at the top of every page!**

In all written homework, you will be graded on the clarity and completeness of your answer. ***No credit*** *will be given for an answer in a calculation without a derivation, even if the answer is correct. A calculation without units is also incorrect.*

Your niece is working on a high-school science fair project, in which she wants to use magnetic concepts to accelerate a marble to high speeds. Since she knows that you are taking PHYS2020, she asks for your help on the following two scenarios.

Scenario 1

Your niece has three identical steel marbles and one strong permanent magnet. Two of the marbles (#2 and #3) are attached to one side of the magnet, as seen in the figure below. You tinker with this setup, and observe the following: when marble #1 is released, it accelerates towards the permanent magnet. It hits, and marble #3 goes flying off the right at an impressive (surprising!) speed (see, e.g. http://tinyurl.com/2bd24vz). Your niece needs help in explaining the physics!

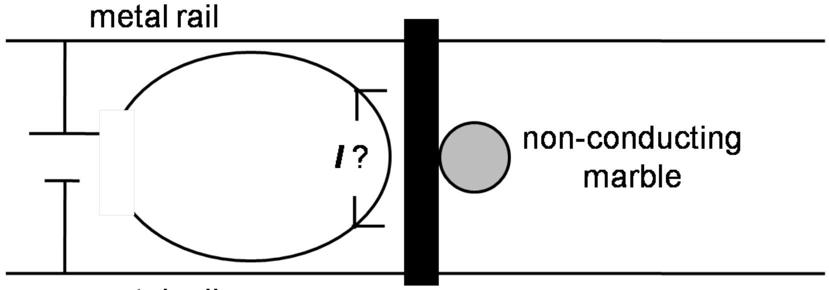


Strong magnets attract steel marbles, and the “binding energy” of the magnet is a very strong function of distance. When the marble touches the magnet, it is "deeply bound", but even being one "marble length" away from the magnet strongly reduces the “binding energy”.

a) Explain what you have seen. (We suggest you assume that there is no friction and there is ideal momentum/energy transfer between the objects. Think about energy and momentum conservation.)
b) Does the orientation of the magnetic dipole (i.e. whether the south pole is left or right) matter? Why or why not?
c) Assume that you move marble #2 from the right side of the magnet to its left side. What would change?
d) How could you further improve the set-up (i.e. achieve an even higher acceleration of marble #3)? Explain your reasoning.

Scenario 2

Your niece is also considering a very different and more ambitious project - here, an electrical device which is based on magnetic concepts is used to launch a non-conducting marble. As shown in the figure, a battery is connected to two metal wires (rails) which are bridged by a sliding conducting carriage. This completes a current-carrying circuit. (The rails continue far off to the right, but do not connect to each other anywhere)



e) Assume that the circuit is powered by a 12 V car battery. All the resistance in the circuit comes primarily from the sliding joint between the carriage and the rails, and is in total a constant 0.5 Ω. The rails are 50 cm apart. How much current runs around the circuit? Indicate the current direction on the diagram.

f) Indicate the direction of the magnetic field between the two rails on the diagram. Using our simple formula for the magnetic field from a long wire, what is the magnitude of the magnetic field exactly halfway between the rails?

g) What is the magnitude of the magnetic force on the sliding metal carriage? Indicate the direction of the force on the diagram. (Approximate the magnetic field as being **uniform** in the vicinity of the carriage, with the magnitude and direction that you calculated in part f).

h) Your niece wants to launch a 100 g marble. The mass of the carriage is 1 kg. What is the acceleration of the marble? What is the final velocity of the marble, if the slider accelerates it over a distance of 1 m (assume constant acceleration and neglect friction and gravity)?

i) What do you think of this project? Do you recommend your niece pursue it? Why/why not? How could you improve the set-up (i.e. achieve a higher acceleration of the marble)? Explain your reasoning.