

Your name: \_\_\_\_\_

TA name: \_\_\_\_\_

## Written HW 4: Magnetic Accelerators

### (due Thurs, Mar 12, 2009 at 5 PM)

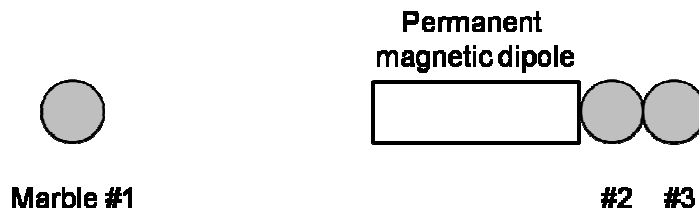
Turn in this written homework in the appropriate slot in the brown Homework Cabinet at the entrance of the HelpRoom, Duane G2B90. Please STAPLE pages together, and **put your name and TA name at the top of every page!**

*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://www.youtube.com/watch?v=RpwmCebivGo&eurl=http://peswiki.com/index.php/Directory:Linear\\_Magnet\\_Accelerators&feature=player\\_embedded](http://www.youtube.com/watch?v=RpwmCebivGo&eurl=http://peswiki.com/index.php/Directory:Linear_Magnet_Accelerators&feature=player_embedded)). Your niece needs help in explaining the physics!

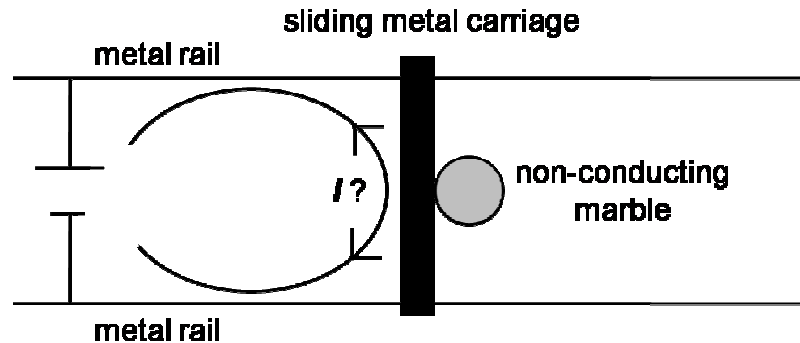


You have (or will have :- ) learned that strong magnets attract steel marbles, and that the “binding energy” of the magnet is a very strong function of distance. (*When the marble touches the magnet, it is “deeply bound”, but even being one “marble length” away from the magnet strongly reduces the “binding energy”.*)

- Think about energy and momentum conservation to explain what you've seen. (We suggest you assume that there is no friction and there is ideal momentum/energy transfer between the objects.)
- Does the orientation of the magnetic dipole (i.e. whether the south pole is left or right) matter (Why or why not)?
- Assume that you move marble #2 from the right side of the magnet to its left side. What would change?
- 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  $0.5 \Omega$ . 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.