Name: ______________________ ID: ______________________ Lab (day/time): ______________

Physics 203
Final Exam
6/10/2019

Collaboration is not allowed. Allowed on your desk are: up to ten 8.5 x 11 inch doubled sided sheets of notes that are bound together, non-communicating scientific calculator, 10 pages of scratch paper, writing utensils, a ruler, and the exam. You will have 110 minutes to complete this exam.

Constants:

$$v_{sound} = 343\,\frac{\mathbf{m}}{\mathbf{s}},\quad c = 3\times 10^{8}\,\frac{\mathbf{m}}{\mathbf{s}},\quad k = 8.99\times 10^{9}\,\mathbf{N}\,\frac{\mathbf{m}^2}{\mathbf{C}^2},\quad \mu_0 = 4\pi\times 10^{-7}\,\frac{\mathbf{Tm}}{\mathbf{A}},$$

$$e = 1.602\times 10^{-19}\,\mathbf{C},\quad m_p = 1.67\times 10^{-27}\,\mathbf{kg},\quad m_e = 9.109\times 10^{-31}\,\mathbf{kg}$$

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1. A 75 W lightbulb is attached to an American wall socket at 120 V.

(P) (ΔV)

a) (1 point) What is the resistance of the lightbulb?

(R)

$$P = \frac{\Delta V^2}{R} \Rightarrow R = \frac{\Delta V^2}{P} = \frac{(120\,V)^2}{75\,W} = 192\,\Omega$$

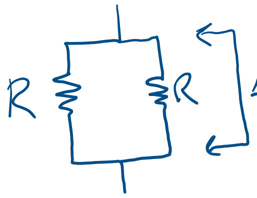
b) (1 point) How much current flows through the lightbulb?

$$\Delta V = IR$$

$$120\,V = I\;192\,\Omega \Rightarrow I = 0.625\,A$$

or $\frac{5}{8}$ A

c) (2 points) You place a second, identical lightbulb in parallel with the first. How long would you need to wait before the lightbulbs have put out 1000 J of energy?



ΔV = same ⇒ two bulbs emitting 75W ⇒ 150 W

$$\frac{1000\,J}{150\,J/s} = 6.67\text{ sec}$$

Or

$$R_{eq} = \frac{1}{\frac{1}{R}+\frac{1}{R}} = \frac{1}{\frac{2}{R}} = \frac{R}{2} = \frac{192}{2} = 96\,\Omega$$

$$P = \frac{\Delta V^2}{R} = \frac{(120\,V)^2}{96\,\Omega} = 150\,W \Rightarrow$$

For questions 2 through 4 **fill in the square** next to all correct answers, a given problem may have more or less than one correct answer. Each correctly chosen answer will receive two points. There are **11 correct answers** in this section and only the first **11** filled in answers will be graded. There is no partial credit.

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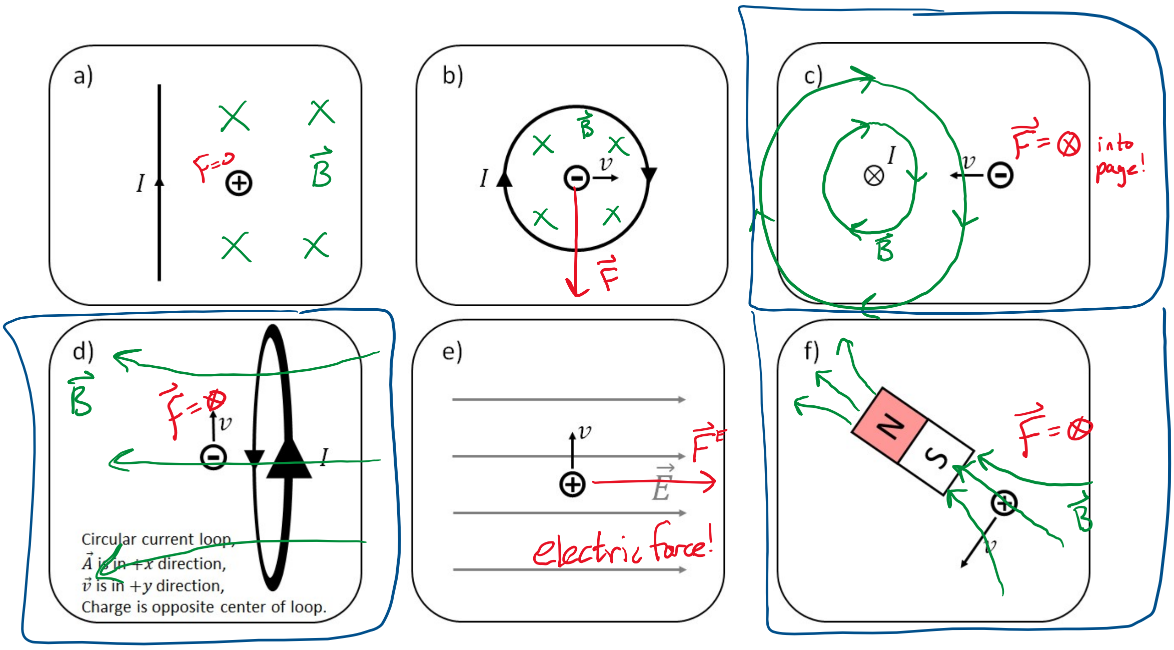
2. Which of the following quantities are scalars?

a) Position
b) Displacement
c) Electric Field
d) Electric Potential Energy
e) Magnetic Flux
f) Electric Force
g) Resistivity
h) Electric Potential Field
i) Induced Current

3. For which of the following situations would the force on the charge be into the page?

a)
b)
c)
d)
e)
f)



4. Which of the following statements are true?

a) Light travels faster in materials with lower index of refraction.

b) Your bathroom mirror creates a virtual image of you when you stand in front of it.

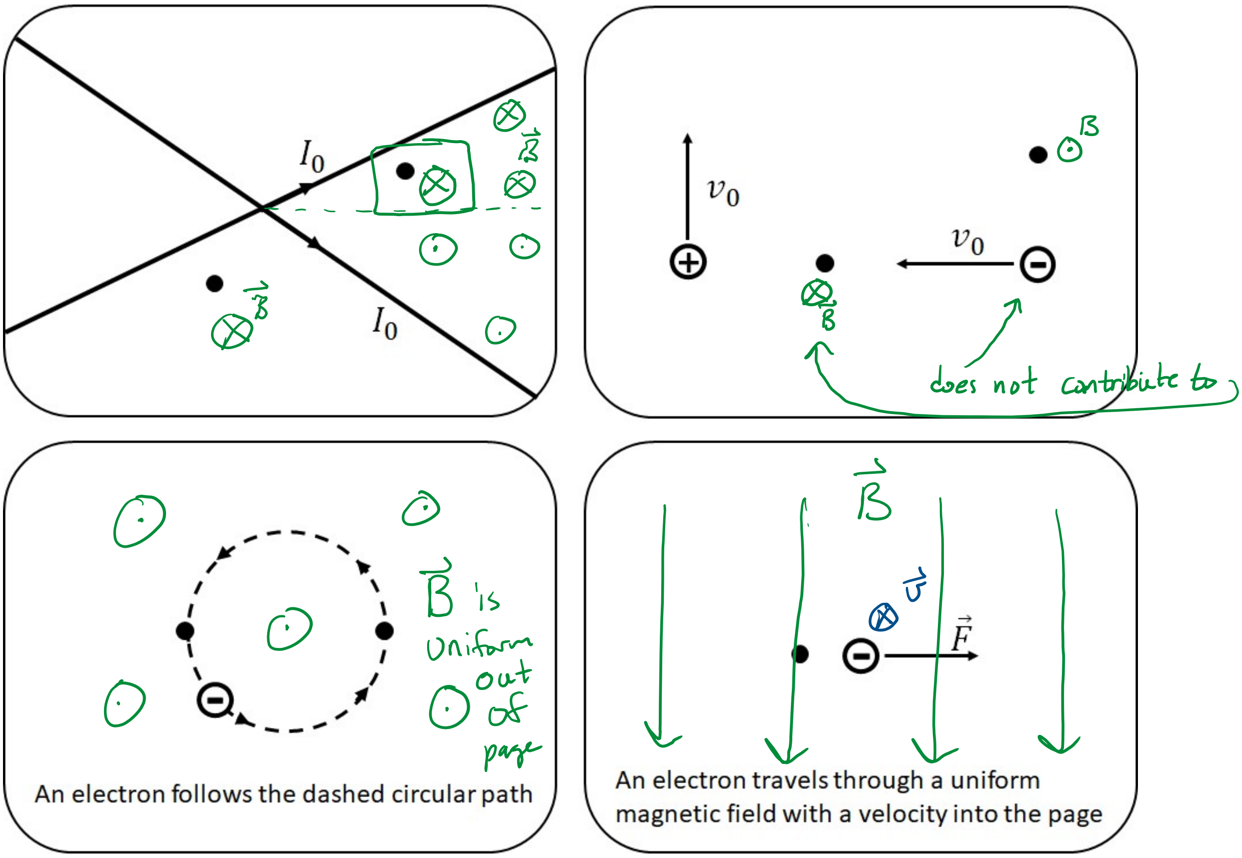
c) When determining whether constructive or destructive interference is happening, path length difference is *not* important.

d) The small angle approximation says that the values of Sine and Cosines are approximately equal when angles are smaller than about 10 degrees.

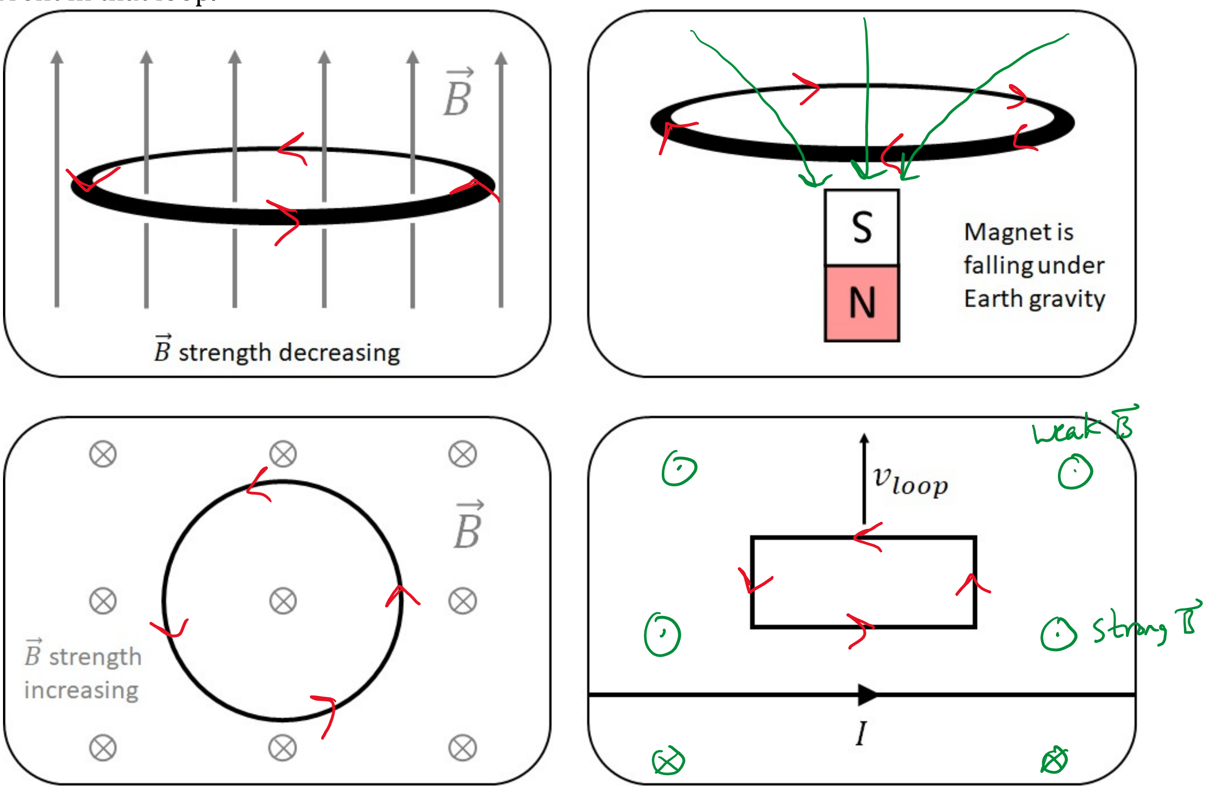
e) Decreasing the slit separation will spread apart the neighboring fringes created by a double slit apparatus.

f) When shining white light through a diffraction grating the blue side of each resulting rainbow will appear further from the central maximum than the corresponding red side.

5. (1 point each dot) For each of the following situations, clearly indicate next to each black dot the direction of the magnetic field at the location of that black dot. If it is zero, state $B = 0$.



6. (1 point each wire) For each loop of wire, clearly indicate on the loop the direction of the induced current in that loop.

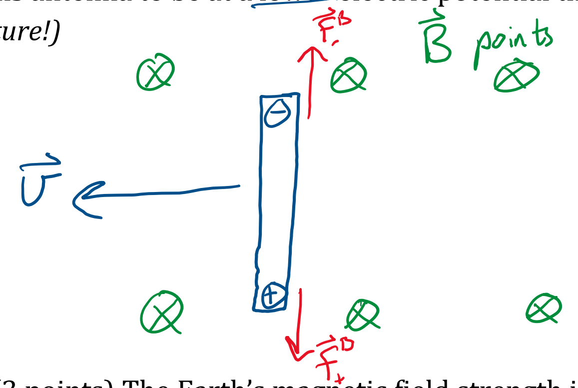


7. Your neighbor's grandpa drives a classic car with an aluminum radio antenna 1.25 meters tall (a thin rod pointed vertically up).

a) (2 points) In which cardinal direction (North, East, South, West) should he drive in order for the top of his antenna to be at a lower electric potential than the bottom of the antenna? *(hint: draw a picture!)*

$\vec{B}$ points North on surface

V lower $\Rightarrow$ negative charges



must drive Westward

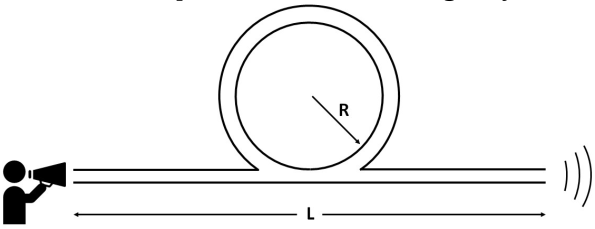
b) (3 points) The Earth's magnetic field strength is 50 μT in Corvallis. How fast would he need to drive to power his 9 V stereo using only the antenna?

$$\Delta V = vBL$$

$$\Rightarrow \quad v = \frac{\Delta V}{BL} = \frac{9\,V}{(50\times10^{-6}\,T)(1.25\,m)} = 144{,}000\ m/s\,!!$$

$$\left(\sim 322{,}000\ \frac{mi}{hr}\,!\right)$$

8. **(5 points)** While practicing your Mongolian overtone singing (the art of singing two distinct frequencies at the same time), you come across an interesting device. The device, pictured below, has a straight open tube joined with a circular open tube. The drawing may not be to scale.



You sing into one end of the tube with a frequency of 400 Hz as well as a frequency of 800 Hz. Out of the other end of the tube, a friend hears one of the frequencies clearly, but not the other. What is the smallest radius for the circular tube which produces this effect?

$f = 400\ Hz \Rightarrow \quad v = f\lambda \Rightarrow \lambda = \frac{343\ m/s}{400\ \frac{1}{s}} = 0.858\ m$

$f = 800\ Hz \Rightarrow \quad \lambda = 0.429\ m$

$PLD = m\lambda$ for one freq

$PLD = (m+\frac{1}{2})\lambda$ for the other

$PLD = 2\pi r$ for both

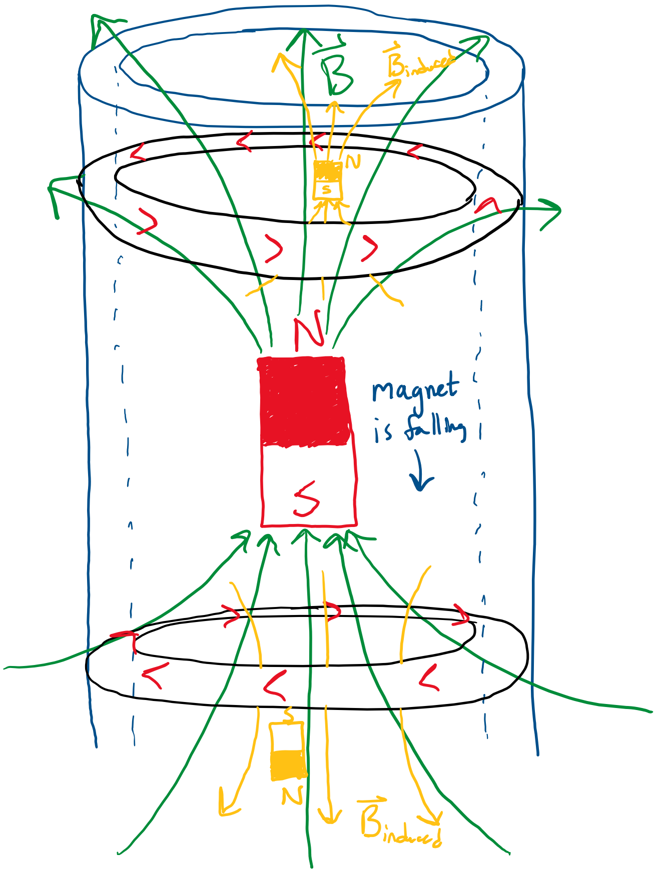
m ↓

$2\pi r = (1)(0.429\ m)$

$2\pi r = (0+\frac{1}{2})(0.858\ m)$

$\Rightarrow \quad r = 6.83\ cm$

9. **(6 points)** Thoroughly explain why a magnet dropped through the middle of a metallic cylinder will accelerate downward at less than 9.8 m/s^2. You may wish to use a combination of words, graphs, and diagrams.



Consider a loop (drawn in black in image) within the cylinder walls above the magnet.

the flux through this loop created by the magnet will be decreasing (and "pointed up") ($\vec{B}$ field in green)

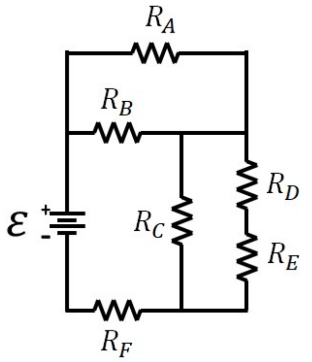
since this loop would like a constant flux, a current (in red) will be induced in the loop, creating an induced magnetic field (in yellow) pointed upward inside the loop.

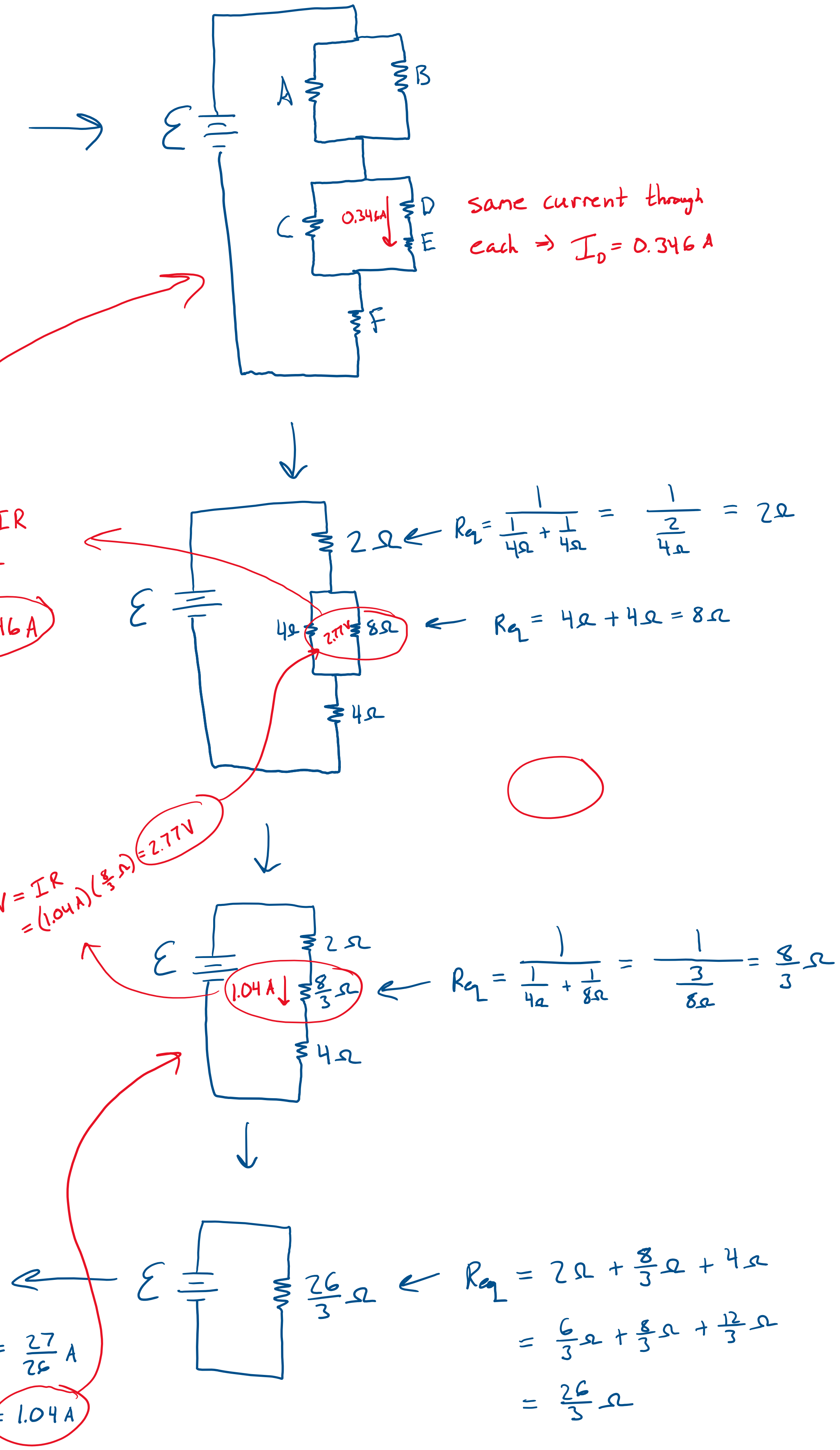
This induced magnetic field will exert an upwards force on the falling magnet. (This induced $\vec{B}$ acts like a little magnet exerting a force on the falling magnet)

$F_{net,y} = -mg + F^B \Rightarrow |\vec{a}| < g$

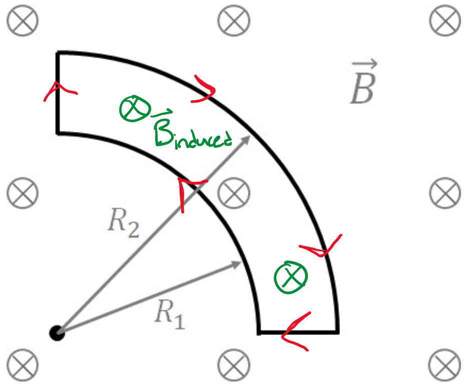
a similar argument can be made for a loop below the magnet. This induced field will point downward resulting in another upward force on the falling magnet.

10. **(8 points)** A circuit is constructed of six identical 4 ohm resistors as shown. If the battery has a voltage of 9 V, how much current flows through resistor D?





11. A loop of copper wire of resistance 0.0132 Ω/m wire in the following shape is placed into a magnetic field as shown. The magnetic field strength then is decreased at a rate of 0.02 T/s. Let R_1 = 3 cm, and R_2 = 5 cm.



a) (2 points) Clearly indicate on the figure which direction the induced current will flow in each of the four sections of the loop.

Flux is decreasing, loop will add more $\vec{B}$ in same direction (into page)

b) (6 points) What is the magnitude of the induced current in the loop?

$$|\Delta V| = I_{induced} R_{loop} = |\mathcal{E}| = \frac{|\Delta \Phi|}{|\Delta t|} = \frac{|\Delta B|}{|\Delta t|}(A) = (0.02\ T/s)\ A_{loop}$$

$$R_{loop} = (0.0132\tfrac{\Omega}{m})\left(\frac{2\pi R_2}{4} + \frac{2\pi R_1}{4} + 2(R_2 - R_1)\right)$$

$$= (0.0132\tfrac{\Omega}{m})\left(\frac{\pi}{2}(.05 - .03) + 2(.05 - .03)\right)m$$

$$= (0.0132\tfrac{\Omega}{m})(0.01\pi + 0.04)m$$

$$R = 9.43 \times 10^{-4}\ \Omega$$

$$A_{loop} = \frac{1}{4}\pi R_2^2 - \frac{1}{4}\pi R_1^2$$

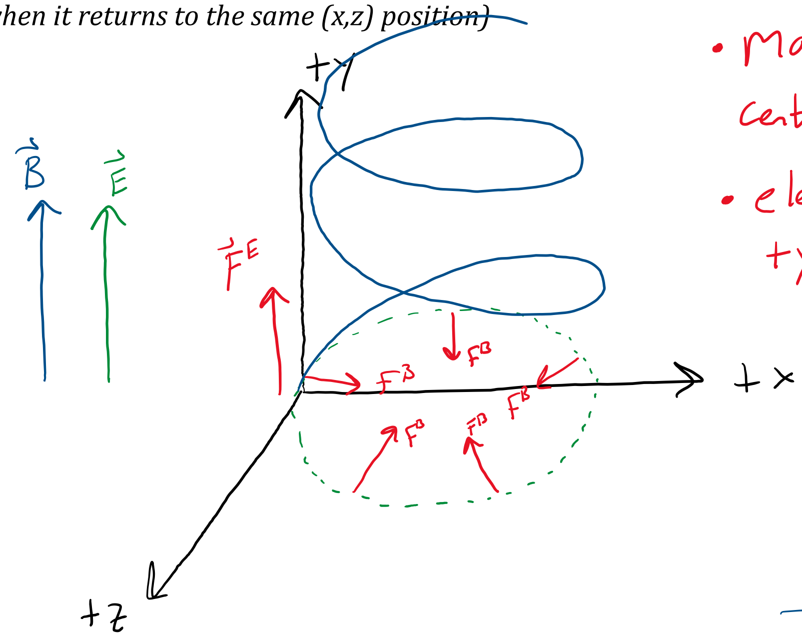
$$= \frac{\pi}{4}(.05^2 - .03^2)\ m^2$$

$$= \frac{\pi}{4}\ 16 \times 10^{-4}\ m^2 = 4\pi \times 10^{-4}\ m^2$$

$$I_{induced} = \frac{A_{loop}}{R_{loop}}\left(\frac{\Delta B}{\Delta t}\right) = \frac{4\pi \times 10^{-4}\ m^2}{9.43 \times 10^{-4}\ \Omega}(0.02\ T/s) = 0.0267\ A$$

$$= 26.7\ mA$$

12. (7 points) A proton is initially at the origin and travelling in the -z direction at a speed v_0. A magnetic field of magnitude 0.3 T is directed in the +y direction. An electric field of magnitude 1300 N/C is also directed in the +y direction. At what y coordinate is the proton when it completes its first revolution? *(when it returns to the same (x,z) position)*



- Magnetic force is towards center of circle/spiral (in x/z direction)
- electric force is in +y direction

divide into x/z circular motion & y-axis motion

x/z – UCM

$$|F^B| = qvB = \frac{mv^2}{r}$$

$$\Rightarrow r = \frac{mv}{qB}$$

$$v = \frac{\text{dist}}{\text{time}} \Rightarrow T = \frac{\text{dist}}{v} = \frac{2\pi r}{v}$$

$$\Rightarrow T = \frac{2\pi}{v}\frac{mv}{qB} = \frac{2\pi m}{qB}$$

$$1\text{ period} = T = \frac{2\pi(1.67\times10^{-27}\text{ kg})}{(1.6\times10^{-19}\text{ C})(0.3\text{ T})}$$

$$T = 2.19\times10^{-7}\text{ sec}$$

$$= 0.22\ \mu s$$

y-axis motion

$$F_{net} = F^E = qE$$

$$a = \frac{F_{net}}{m} = \frac{qE}{m}$$

$$\Delta v = \frac{qE}{m}\Delta t$$

$$\Delta y = \frac{1}{2}\frac{qE}{m}\Delta t^2$$

$$\Rightarrow \Delta y = \frac{1}{2}\frac{qE}{m}\left(\frac{2\pi m}{qB}\right)^2$$

$$= \frac{1}{2}\frac{qE}{m}\frac{4\pi^2 m^2}{q^2 B^2}$$

$$\Delta y = 2\pi^2\frac{mE}{qB^2}$$

$$= 2\pi^2\frac{(1.67\times10^{-27}\text{ kg})(1300\text{ N/C})}{(1.6\times10^{-19}\text{ C})(0.3\text{ T})^2}$$

$$\Delta y = 2.98\text{ mm}$$