Name:
Bamfield Number:
Student Number:

Science One Physics Midterm #4

March 18, 2014

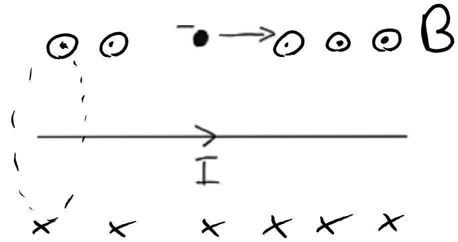
Questions 1-8: Multiple Choice: 2 point each
Questions 9-11: Explain your work: 18 points total

Multiple choice answers:

#1	C
#2	A
#3	B
#4	D
#5	E
#6	A
#7	D
#8	C

Formula sheet at the back (you can remove it)

Question 1: In the picture below, the moving charge will be deflected



A) into the page.
B) out of the page
C) upwards
D) downwards
E) None of the above.

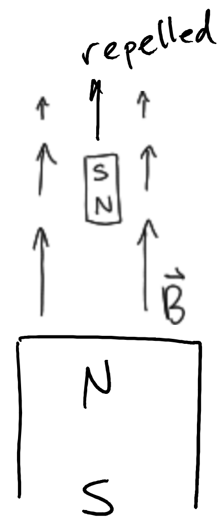
$\vec{v}\times\vec{B}$: ↓

$q\vec{v}\times\vec{B}$: ↑ since q −ve

$\vec{F} = q\vec{v}\times\vec{B}$

Question 2: A magnet sits in a non-uniform magnetic field as shown to the right. Ignoring gravity, we can say that the magnet will

A) accelerate upward
B) accelerate downward
C) experience no net force



field like from this magnet

$\vec{E}$: direction of initial acceleration ↓

Question 3: The picture above shows the actual path that a proton which starts from rest will follow in the presence of certain uniform electric and magnetic fields. We can say that:

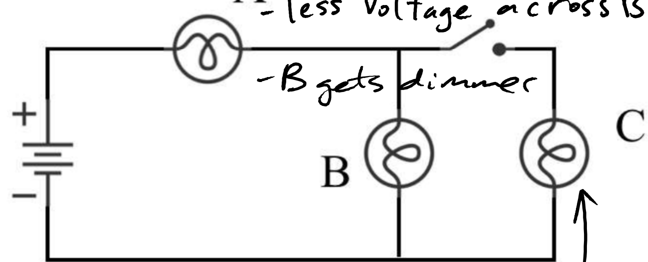
$\vec{B}$: causes turning: $\vec{F} = q\vec{v}\times\vec{B}$ $\vec{v}$↓ →$\vec{F}$ $\vec{B}$ into page gives right result.

A) the electric field points to the right and the magnetic field points into the page
B) the electric field points down and the magnetic field points into the page
C) the electric field points to the right and the magnetic field points downward
D) the electric field points down and the magnetic field points to the right
E) the electric field points up and the magnetic field points downward
F) the electric field points up and the magnetic field points into the page

Question 4: What happens when the switch is closed?

A) B and C both get brighter
B) B gets brighter and C gets dimmer
C) Nothing happens
D) B gets dimmer and C get brighter
E) B and C both get dimmer

- switch closed ⇒ less net resistance in BC part
- more current through A
- less voltage across B
- B gets dimmer



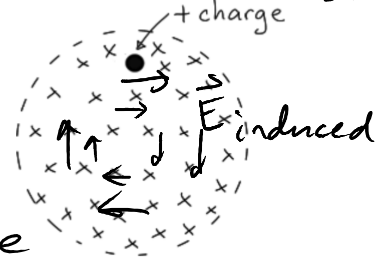
$V_B = V_{Batt} - I \cdot R_A$

Question 5: Current flows through a wire that is thick at one end and thin at another end. Which of the following change from the thick end to the thin end?

A) Current density → greater since same total current
B) Conductivity → same since same material
C) Electric field
D) both A) and B)
E) both A) and C)
F) both B) and C)
G) all of A), B), and C)

$\vec{J} = \sigma \vec{E}$ ∴ $\vec{E}$ greater (J greater, σ same)

Question 6: The picture to the right shows a positive charge sitting in a magnetic field produced by a solenoid. If the current in the solenoid is decreased, we can say that the charge will initially move



A) to the right
B) to the left
C) upward
D) downward
E) into the page
F) out of the page
G) None of the above: it will stay still.

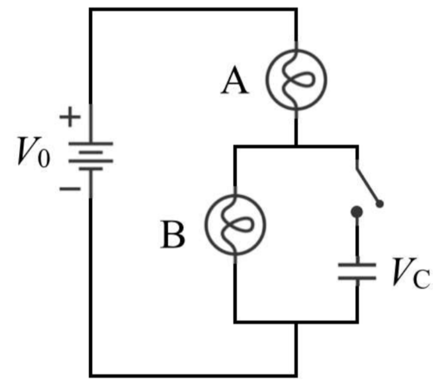
$\frac{d\vec{B}}{dt}$: out of page

$-\frac{d\vec{B}}{dt}$: into page $\xrightarrow{RHR}$ $\vec{E}$ induced circulating clockwise

∴ $\vec{F} = q\vec{E}$ to right

Question 7: A bunch of Science One students would like to increase the EMF of a generator they have built (that spins a coil of wire in a magnetic field). Which of the following will **not** help:

A) Increasing the magnetic field strength
B) Increasing the area of the loop
C) Increasing the number of turns of wire
D) Decreasing the resistance of the wire → increases current but not EMF



Question 8: When the switch is closed, what best describes what happens in the circuit above?

A) Light bulbs A and B both suddenly go dim. They then return to their previous brightness.
B) Light bulbs A and B both suddenly go dim. They slowly return to different brightness than when the switch was closed.
C) Light bulb B goes out and A suddenly gets brighter. They then slowly return to their previous brightness.
D) Light bulb B goes out and A suddenly gets brighter. They slowly return to different brightness than when the switch was closed.
E) Light bulbs A and B both suddenly go brighter. They then return to their previous brightness.

capacitor

Initially:  like wire, so B goes off as all current diverted to this zero resistance path. A brighter since less net resistance in circuit → more current.

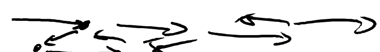
At end: capacitor acts like gap in circuit since no more charge flows to it

∴ B + A back to original brightness

Question 10: Give a brief explanation (1-2 sentences) for each of the following:

a) If electrons accelerate in an electric field, why doesn't current increase steadily with time when we apply a voltage to a conductor? **(2 points)**

The electrons only accelerate until they interact with something (Plinko model), then they start again. The

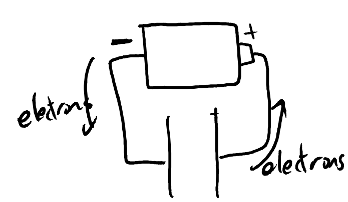


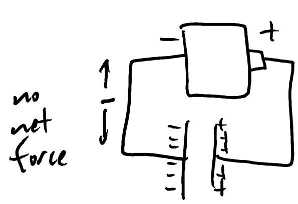
velocity of each electron increases only between collisions while the average velocity of all the electrons (which determines the current) remains constant.

b) Why does a magnet stick to a refrigerator door if the door isn't a magnet? **(2 points)**

The electrons in the metal fridge door are like tiny magnetic dipoles which are usually not all aligned with each other. When the magnet is nearby the magnetic moments of the electrons align with the magnetic field of the magnet, after which the door itself acts like a magnet and attracts the permanent magnet.

c) When we connect a capacitor to a battery, why does current flow out of the battery for a while and then stop? **(2 points)**

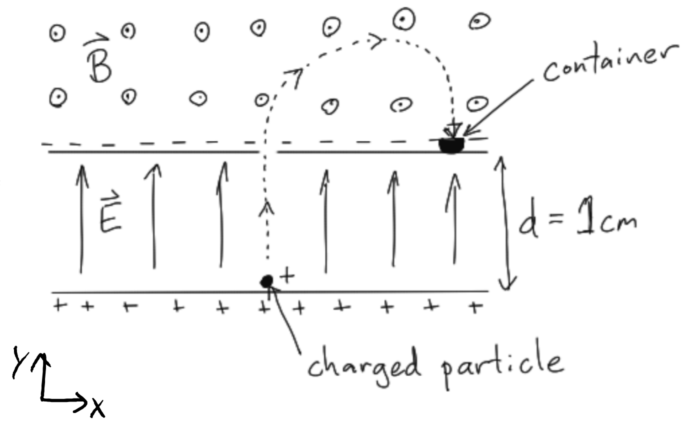




Initially, electrons are attracted by the higher potential on the + side of the battery & repelled by the lower potential on the - side of the battery.

After some time, the charges have built up on the plates and these exert forces such that no additional charges flow (potential on plate same as on nearby battery terminal.

Question 11: A charged particle with mass 10^{-15}kg and charge 5×10^{-10}C starts at rest at the bottom of a capacitor in which the electric field is 10,000V/m. The particle accelerates upward, passing through a hole in the top plate and entering a uniform magnetic field. If we want the particle to end up in a collector that is 2cm from the hole, as shown, how strong a magnetic field do we need?
(6 points)



In the electric field, we have

$$m\vec{a} = \vec{F} = \vec{E}q$$

So we have constant upward acceleration

$$a_y = \frac{Eq}{m}$$

Since the particle starts from rest at $y=0$, we get:

$$V_y = \frac{Eq}{m}t \quad \text{and} \quad y = \frac{1}{2}\left(\frac{Eq}{m}\right)t^2$$

Eliminating t, we get $V_y = \sqrt{2\frac{Eq}{m}y}$ ↖ Can also use $V_f^2 = V_i^2 + 2ad$

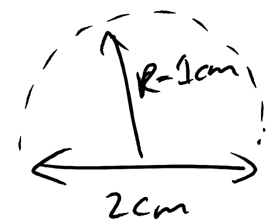
So the speed at the top of the capacitor is

$$V_y = \sqrt{2 \cdot \frac{10000\,V/m \cdot 5\times10^{-10}C}{10^{-15}kg} \cdot 0.01m} = 10^4\,m/s$$

In the magnetic field, the particle moves in a circular path with constant speed 10^4m/s. We have $a = \frac{V^2}{R}$. This acceleration is due to the magnetic force, so by $F=ma$, we have:

$$qvB = \frac{mv^2}{R}$$

$$\Rightarrow \quad B = \frac{mv}{qR}$$

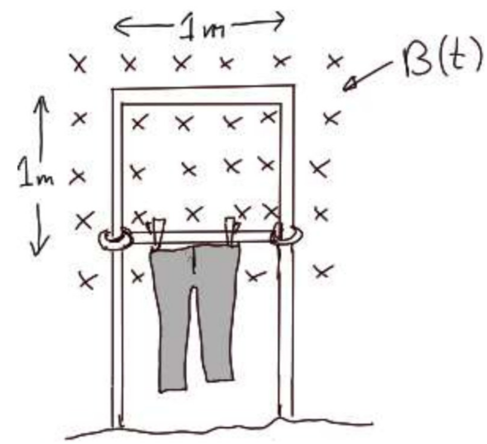


$$= \frac{10^{-15}\,kg \cdot 10^{4}\,m/s}{5\times10^{-10}\,C \cdot 0.01\,m}$$

$$= 2T$$

We need a 2T magnetic field.

Question 12: For reasons unknown, Sally would like to hang up a pair of pants using electromagnetic induction instead of an ordinary clothesline. She builds a conducting frame with a conducting bar that touches the two sides but can move up and down freely without friction. She hangs a damp pair of pants on the bar, and then turns on an increasing uniform magnetic field.



a) Explain why this allows Sally to hold up the pants. **(3 points)**

b) If the mass of the bar + pants is 1kg, and the resistance of the loop created by the bar and frame is 0.1 Ohms, determine B(t) so that the pants will stay still (or at least find an equation that B(t) must satisfy). *Ignore any magnetic fields other than the one Sally turns on.* **(3+ points)**

a) The increasing magnetic field gives an increasing flux through the square conducting loop. This results in an EMF in the loop by Faraday's Law (caused by the induced electric field). The EMF results in a current, which by Lenz's Law is counterclockwis (so that the magnetic field it generates opposes the change). Since we have a current to the right in the movable bar and since this is in a magnetic field, there will be an upward magnetic force on the bar that can (if B(t) is chosen correctly) balance the downward force of gravity.

b) Quantitatively, we need

$$F_{mag} = F_{grav}$$

$$\Rightarrow I L B = mg$$

Now $I = \frac{\mathcal{E}}{R}$ and $|\mathcal{E}| = \frac{d\Phi_B}{dt} = A \cdot \frac{dB}{dt}$.

Putting everything together, we require that:

$$\frac{A}{R} \cdot \frac{dB}{dt} \cdot L \cdot B = mg$$

$$\Rightarrow B \cdot \frac{dB}{dt} = \frac{mgR}{AL} = \frac{1\,\text{kg} \cdot 9.8\,\text{m/s}^2 \cdot 0.1\,\Omega}{1\,\text{m}^2 \cdot 1\,\text{m}}$$

$$\Rightarrow B \cdot \frac{dB}{dt} = 0.98\,\text{T}^2/\text{s}$$

To solve, note that the LHS is $\frac{d}{dt}\left(\frac{1}{2}B^2\right)$ so

we want: $$\frac{d}{dt}\left(\frac{1}{2}B^2\right) = 0.98\,\text{T}^2/\text{s}$$

$$\Rightarrow \frac{1}{2}B^2 = (0.98\,\text{T}^2/\text{s})\,t + \frac{1}{2}B_0^2$$

$$\Rightarrow B(t) = \sqrt{(1.96\,\text{T}^2/\text{s})\,t + B_0^2}$$

B_0 = initial magnetic field