Evan's Solutions

Sunday, June 5, 2022 12:50 PM

Name:______________________________ ID:______________________________

Physics 203

Final Exam

6/6/2022

Collaboration is not allowed. Allowed on your desk are: ten 8.5 x 11 inch doubled sided sheets of notes that are bound together, non-communicating graphing scientific calculator, 1 page of scratch paper, writing utensils, and the exam. You will have 110 minutes to complete this exam.

If you have any questions, especially about the definition of a word or phrase given in a question, please raise your hand and ask! We are happy to clarify!

Constants

$m_{proton} = 1.67 \times 10^{-27}$ kg

$m_{electron} = 9.11 \times 10^{-31}$ kg

$e = 1.60 \times 10^{-19}$ C

$k = 8.99 \times 10^{9}$ N m^2/C^2

For questions 1 through 4 **fill in the square** next to all correct answers. A given problem may have more than one correct answer. Each correctly bubbled answer will receive two points. There are **9** correct answers in this section and only the first **9** filled in answers will be graded. There is no partial credit.

1. Which of the following statements are true regarding a typical insulator?

   □ (a) Insulators have electrons that can move freely throughout the material.

   □ (b) Insulators have neutrons that can move freely throughout the material.

   □ (c) Insulators have protons that can move freely throughout the material.

   ● (d) Insulators have no free charges that can move freely throughout the material.

   □ (e) Insulators are unable to be polarized.

   □ (f) Insulators are more easily polarized than conductors.

   ● (g) Conductors are more easily polarized than insulators.

2. Which of the following statements are true?

   □ (a) Equipotential lines point towards decreasing electric field values.

   ● (b) Electric field lines point towards decreasing electric potential values.

   ● (c) The electric field is the negative of the slope of the electric potential vs distance.

   □ (d) The electric field is the negative of the area of the electric potential vs distance.

   □ (e) The electric field is the same quantity as the electric potential.

   □ (f) The electric field and electric potential are different quantities, therefore they are not mathematically connected to each other.

3. The electric potential is 4 Volts at x = 0 meters and 6 Volts at x = 1 meter. If the electric potential at x = 1 meter changes to 12 Volts and the electric potential at x = 0 meters remains 4 Volts, by how much does the strength of the average electric field between the two points change?

   □ (a) Quarters

   □ (b) Halves

   □ (c) Stays the same

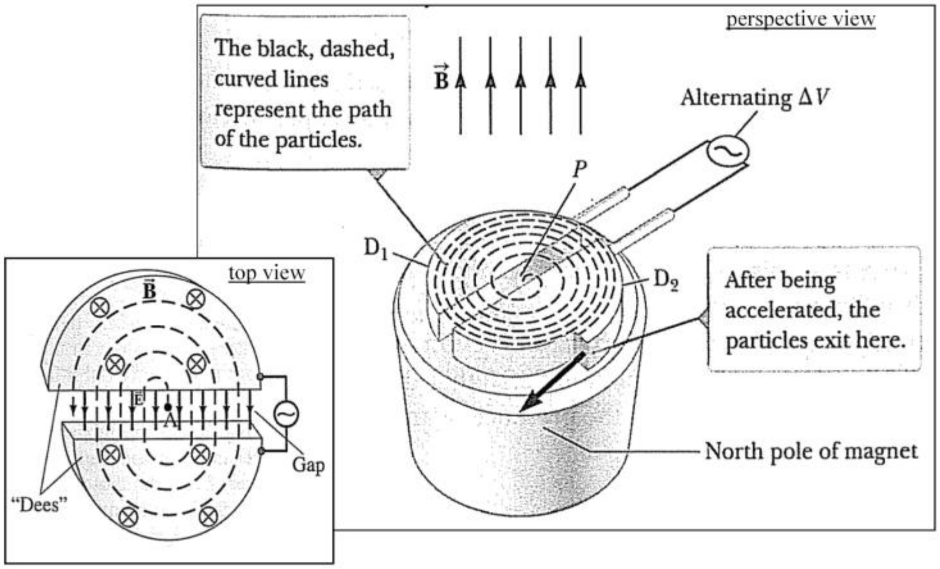
   □ (d) Doubles

   ● (e) Quadruples

$E = -\frac{\Delta V}{\Delta x} \Rightarrow$ init) $E = -\frac{2V}{1m} = -2\frac{V}{m}$

final) $E = -\frac{8V}{1m} = -8\, V/m$

A cyclotron is a device used to accelerate electrons emitted at the center (point A on the left diagram, point P on the right diagram) to higher and higher speeds before they are ejected from the device. The diagrams show two perspectives of the device.



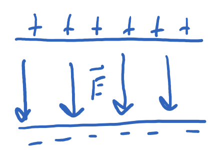
4. Which one of the following are correct considering the electric field (E) in the gap between the two "Dees"?

● (a) The electric field speeds up the electrons. $\vec{F} = m\vec{a} = q\vec{E}$

□ (b) The electric field puts the electrons into uniform circular motion.

□ (c) The electric field has no effect on the electrons.

Refer to the electric field (E) as pictured in the top view diagram. Which one of the following are possible considering the charge on the flat, horizontal surfaces on the top and bottom of the gap?



● (d) The top surface has a net positive charge while the bottom a net negative charge.

□ (e) The top surface has a net negative charge while the bottom a net positive charge.

□ (f) There are no charges on the surfaces.

Which one of the following are correct considering the magnetic field (B) in the two "Dees"?

□ (g) The magnetic field speeds up the electrons. $\vec{F}$ is $\perp$ to $\vec{v}$ $\Rightarrow$ cannot speed up!

● (h) The magnetic field puts the electrons into uniform circular motion.

□ (i) The magnetic field has no effect on the electrons.

As the speed (v) of the electrons increases, so does the radius (r) of their circular motion. Which of the following ratios is equivalent to the ratio of the speed over the radius (v/r)? Note: m is the mass of the electron.

● (j) $\frac{qB}{m}$ □ (k) $\frac{B}{qm}$ □ (l) $\frac{mB}{q}$ □ (o) $\frac{q}{mB}$

$F_{net} = F^B \Rightarrow \frac{mv^2}{r} = qvB \Rightarrow \frac{v}{r} = \frac{qB}{m}$

5. (8 points) Written on a lightbulb, in faint grey writing, are the words "50 Watts". This means that if the lightbulb were connected to a typical American power outlet of 110 V (those holes in the wall), it would emit 50 Watts of power.

(a) What is the resistance of such a lightbulb?

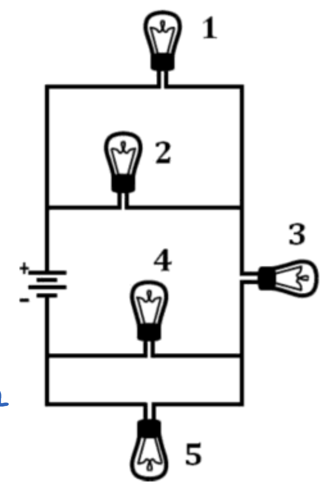
$P = I^2 R$

$= \Delta V^2 / R$

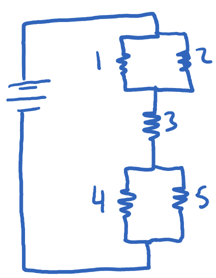
$= I \Delta V$

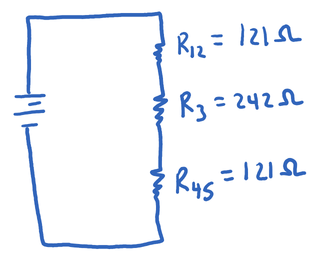
$50\ \text{W} = \frac{(110\ \text{V})^2}{R} \Rightarrow \boxed{R = 242\ \Omega}$

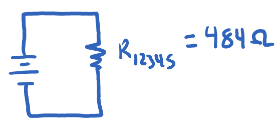
Five identical "50 Watt" lightbulbs are arranged in a circuit as shown. Each bulb is numbered 1 through 5 for identification (these are not the resistance values!). Show your work.



(b) What is the total equivalent resistance of this circuit?



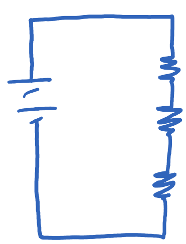




$\boxed{R_{tot} = 484\ \Omega}$

(c) If the battery has a 1.936 V potential difference, what is the potential difference across resistor 4?

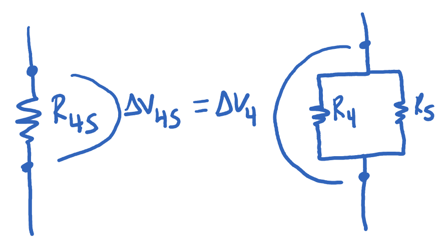
$I_{tot} = \frac{\Delta V}{R_{tot}} = \frac{1.936\ \text{V}}{484\ \Omega} = 4 \times 10^{-3}\ \text{A} = 4\ \text{mA}$



$R_{45} = 121\ \Omega$

$I_{45} = I_{tot} = 4\ \text{mA}$

$\Delta V_{45} = 0.484\ \text{V}$



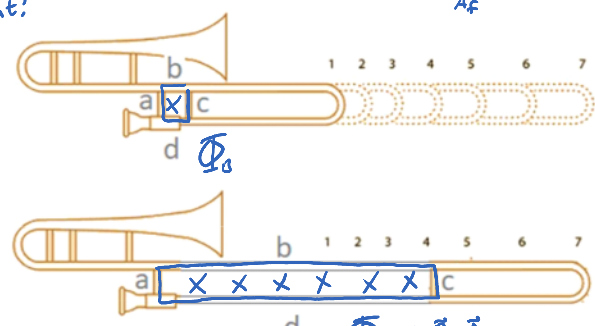
$\Delta V_4 = 0.484\ \text{V}$ or $484\ \text{mV}$

6. (7 points) A musician is playing a trombone near the surface of the Earth, and is standing such that the Earth's magnetic field is 40 uT pointing directly into the page (perpendicular to the trombone). The musician can increase or decrease the length of the trombone. When the musician is playing the trombone as seen in the top image, the area enclosed by lengths a, b, c, and d is 0.023 m². The musician then increases the length of the trombone to position 7 as seen in the bottom image. It takes the musician 0.10 seconds to increase the length. The new areas enclosed by lengths a, b, c, and d is 8 times larger than the initial area of 0.023 m².

A_i Δt A_f stays constant?

(a) If the total resistance of lengths a, b, c, and d is 3 ohms, what is the magnitude of current within that loop during the 0.10 seconds that the musician is increasing the length?

(b) Is the current from part (a) traveling along the a, b, c, d loop clockwise or counterclockwise?



a)

$$|\mathcal{E}| = IR$$

$$|\mathcal{E}| = \left| -\frac{\Delta \Phi}{\Delta t} \right| = \frac{\Delta \Phi}{\Delta t} = \frac{\Delta (BA\cos\theta)}{\Delta t} = \frac{B \cos\theta \, \Delta A}{\Delta t}$$

$$= \frac{(40 \times 10^{-6}\,T)\left[8(0.023\,m^2) - 1(0.023\,m^2)\right]}{0.1\,s}$$

$$|\mathcal{E}| = 64.4\,mV$$
$$= I\,(3\,\Omega) \Rightarrow \boxed{I = 21.5\,mA}$$

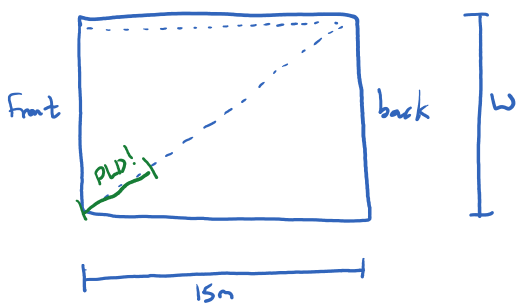
B) counterclockwise

sound
light speeds

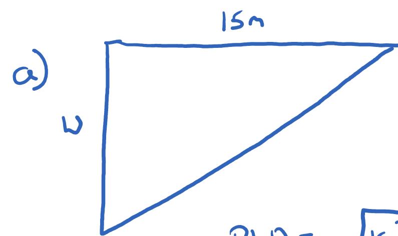
7. (7 points) You are designing a rectangular movie theater room in your house. The sound quality of the bass frequencies are of particular importance to you. With a quick estimation, you choose to focus on sound of 100 Hz. There will be two in-phase speakers (subwoofers) at the front right and front left of the room. You would like there to be no quiet spots of destructive interference at the back of the theater, where you will be sitting. The room measures 15 meters from the front to the back.

(a) How wide should you design the room such that the two back corners of the room are the only quiet spots along the back wall? (hint: do not use young's double slit for this question)

(b) Humans can hear sound of frequencies between 50 Hz - 20,000 Hz. Would you expect frequencies lower than 100 Hz to have more, or fewer quiet spots along the back wall of your theater? Explain using words, diagrams, math, etc.



a)



$PLD = \sqrt{15m^2 + w^2} - 15m$

$PLD = \frac{1}{2}\lambda \Rightarrow$ destructive

What is λ?

$v = f\lambda$ $\quad v = 343\ m/s$ $\quad f = 100\ Hz$

$\Rightarrow \lambda = 3.43\ m$

$\frac{1}{2}(3.43) = \sqrt{15^2 + w^2} - 15$

$\Rightarrow 15^2 + w^2 = 279.4\ m^2$

$\Rightarrow \boxed{w = 7.38\ m}$

b) $\uparrow\lambda = \frac{v}{f\downarrow} \Rightarrow$ Smaller $f \Rightarrow$ larger λ

$L^2 + W^2 = \left(\frac{1}{2}\lambda + L\right)^2$

$\Downarrow$

larger λ gives a larger width between destructive fringes

$\Downarrow$

fewer

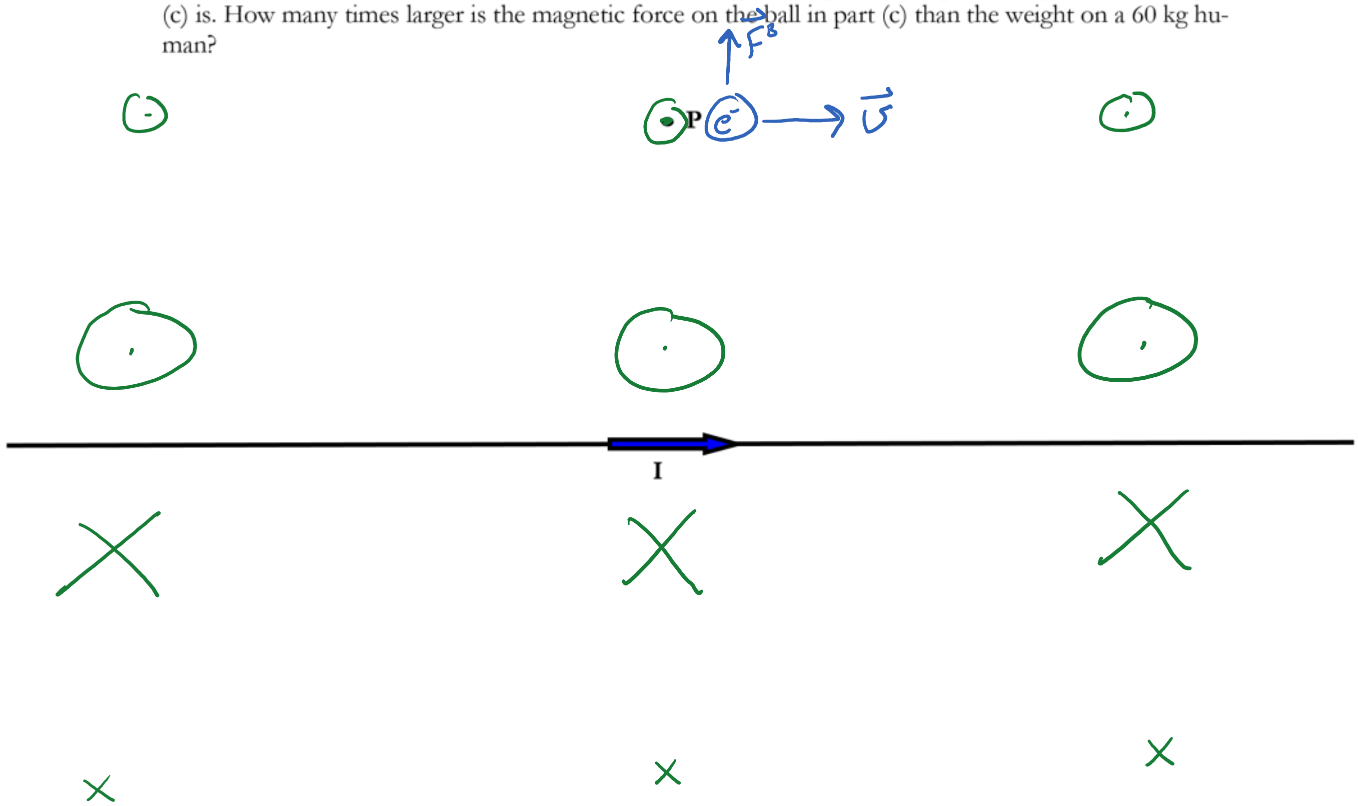
8. (12 points) A long straight wire carries a current **I** to the right. Ignore gravity when analyzing the forces on electrons.

(a) Sketch a physical representation of the wire's magnetic field both above and below the wire. You can assume your representation is for a cross-sectional slice of the field in the plane of the paper/screen. Your sketch should use dots (·) to represent *out of the page* and an (x) to represent *into the page*. You should represent larger magnetic field by using larger symbols (smaller x vs larger X). There should be at least 8 locations (4 above and 4 below) at which you represent the field. Not all the positions can be the same distance to the wire and one of the positions should be at point P.

(b) If electrons are moving through point P, and they experience a force directly away from the wire (upwards in the figure), what direction are the electrons moving? Explain the reasoning behind your answer.

(c) Assume there is a small metal ball with an Avogadro's number (6.02×10^{23}) of excess electrons traveling at 25 m/s through point P in the direction you answered in part (b). If the magnetic field strength at point P is 3 T (similar to what can be found in MRI machines), how much force is exerted on the ball?

(d) Use *Known Values* and *Order of Magnitude* sensemaking techniques to grasp how large the force in part (c) is. How many times larger is the magnetic force on the ball in part (c) than the weight on a 60 kg human?



b) right hand rule (Using left hand b/c electron has negative charge)

fingers ($\vec{B}$) points out of page; palm ($\vec{F}$) points upwards ($+\hat{y}$) ⇒ thumb ($\vec{v}$) must point to the right

c) $\vec{F}^B = q\,\vec{v} \times \vec{B} \Rightarrow |\vec{F}^B| = |q||\vec{v}||\vec{B}| \sin\theta$

huge!!!

$|\vec{F}^B| = (6.02\times10^{23})(1.602\times10^{-19}C)(25\ m/s)(3T)(1)$

$= 7.23\times10^{6}\ N = 7.23\ MN$

d) 60 kg human, weight $= |\vec{F}^g| = mg$ $\Rightarrow$ 588 N

$\Rightarrow F^B =$ 12,300 times larger than a human's weight!

$\Rightarrow$ 5 orders of magnitude larger!!