PHYS 2212 Test 3
Fall 2014

Name(print) Leopold "Butters" Stotch Lab Section ____________

Lab section by day and time: Greco(N,P), Zangwill(Q)						
Monday	12:05-2:55pm	N01 or Q01	3:05-5:55pm	N02 or P01	6:05-8:55pm	Q02 or P02
Tuesday	12:05-2:55pm	N03 or P03	3:05-5:55pm	Q03 or P04	6:05-8:55pm	
Wednesday	12:05-2:55pm	N05 or P05	3:05-5:55pm	Q05 or P06	6:05-8:55pm	N04 or Q04
Thursday	12:05-2:55pm	P07 or N06	3:05-5:55pm	N07 or Q06	6:05-8:55pm	

Instructions

- Read all problems carefully before attempting to solve them.
- Your work must be legible, and the organization must be clear.
- You must show all work, including correct vector notation.
- **Correct answers without adequate explanation will be counted wrong.**
- Incorrect work or explanations mixed in with correct work will be counted wrong. Cross out anything you do not want us to grade
- Make explanations correct but brief. You do not need to write a lot of prose.
- Include diagrams!
- **Show what goes into a calculation, not just the final number, e.g.:** $\frac{a \cdot b}{c \cdot d} = \frac{(8\times10^{-3})(5\times10^{6})}{(2\times10^{-5})(4\times10^{4})} = 5 \times 10^4$
- Give standard SI units with your results.

Unless specifically asked to derive a result, you may start from the formulas given on the formula sheet, including equations corresponding to the fundamental concepts. If a formula you need is not given, you must derive it.

If you cannot do some portion of a problem, invent a symbol for the quantity you can not calculate (explain that you are doing this), and use it to do the rest of the problem.

Honor Pledge

"In accordance with the Georgia Tech Honor Code, I have neither given nor received unauthorized aid on this test."

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Sign your name on the line above

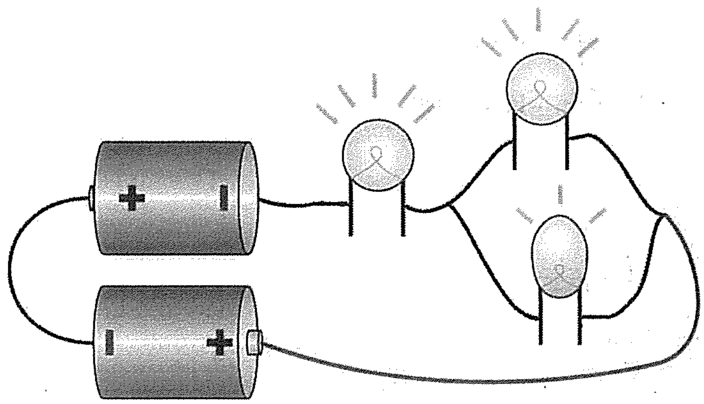
PHYS 2212

Please do not write on this page.

Problem	Score	Grader
Problem 1 (25 pts)		
Problem 2 (25 pts)		
Problem 3 (25 pts)		
Problem 4 (25 pts)		

Problem 1 (25 Points)

In lab you used round and oblong light bulbs and measured the current in these bulbs when you hooked them up to a battery. You connect a single round bulb to a single battery and measure a current I_r in the bulb. You then connect a single oblong bulb to a single battery and measure a current I_o in the bulb. Two round bulbs and a single oblong bulb are now connected with two batteries as indicated in the diagram. Determine the current through the oblong bulb. Be sure to show all of your work and start from a fundamental principle.



$\mathcal{E}mf = I_r R_r \Rightarrow R_r = \frac{\mathcal{E}mf}{I_r}$

$\mathcal{E}mf = I_o R_o \Rightarrow R_o = \frac{\mathcal{E}mf}{I_o}$ (3 pts)

Loop rule)
$\Delta V = 0$

$\Delta V_{bat} + \Delta V_r + \Delta V_o = 0 \Rightarrow 2\,\mathcal{E}mf - I_1 R_r - I_3 R_o = 0$ (i) 5 pts

$\Delta V_{bat} + \Delta V_r + \Delta V_r = 0 \Rightarrow 2\,\mathcal{E}mf - I_1 R_r - I_2 R_r = 0$ (ii) 5 pts

$\Delta V_r + \Delta V_o = 0 \Rightarrow I_2 R_r - I_3 R_o = 0$ (iii) 5 pts

Node Rule)
$I_1 = I_2 + I_3$ (iv) 2 pts

Using (iii): $I_2 R_r = I_3 R_o \Rightarrow I_2\left(\frac{\mathcal{E}mf}{I_r}\right) = I_3\left(\frac{\mathcal{E}mf}{I_o}\right) \Rightarrow I_2 = I_3\left(\frac{I_r}{I_o}\right)$ (v)

Using (iv): $I_1 = I_2 + I_3 \Rightarrow I_1 = I_3\left(\frac{I_r}{I_o}\right) + I_3$ (vi) (used (v))

Using (i): $2\,\mathcal{E}mf - I_1\left(\frac{\mathcal{E}mf}{I_r}\right) - I_3\left(\frac{\mathcal{E}mf}{I_o}\right) = 0$

$2\,\mathcal{E}mf - \left[I_3\left(\frac{I_r}{I_o}\right) + I_3\right]\left(\frac{\mathcal{E}mf}{I_r}\right) - I_3\left(\frac{\mathcal{E}mf}{I_o}\right) = 0$ [used (vi)]

$2\,\mathcal{E}mf - I_3\left(\frac{\cancel{I_r}}{I_o}\right)\left(\frac{\mathcal{E}mf}{\cancel{I_r}}\right) - I_3\left(\frac{\mathcal{E}mf}{I_r}\right) - I_3\left(\frac{\mathcal{E}mf}{I_o}\right) = 0$ [factor out $\mathcal{E}mf$]

$2 - I_3\left(\frac{1}{I_o}\right) - I_3\left(\frac{1}{I_r}\right) - I_3\left(\frac{1}{I_o}\right) = 0$

$2 = \frac{I_3}{I_r} + \frac{2I_3}{I_o}$

$2 = I_3\left(\frac{I_o + 2I_r}{I_r I_o}\right) \Rightarrow \boxed{I_3 = 2\left(\frac{I_r I_o}{I_o + 2I_r}\right)}$ 5 pts

Problem 2 (25 Points)

Three identical batteries (each with an emf equal to V) are connected to six identical resistors (each with resistance R) as shown in the diagram below.

Starting @ 1 and going CCW.

a) $-IR - IR + V - IR - IR + V - IR - IR + V = 0$

$\Rightarrow 3V = 6IR$

$\Rightarrow I = \frac{1}{2}\frac{V}{R}$

b) $V_1 - V_3 = \Delta V_{31} = \Delta V_{32} + \Delta V_{21}$

$= IR + IR$

$= \frac{V}{2} + \frac{V}{2}$

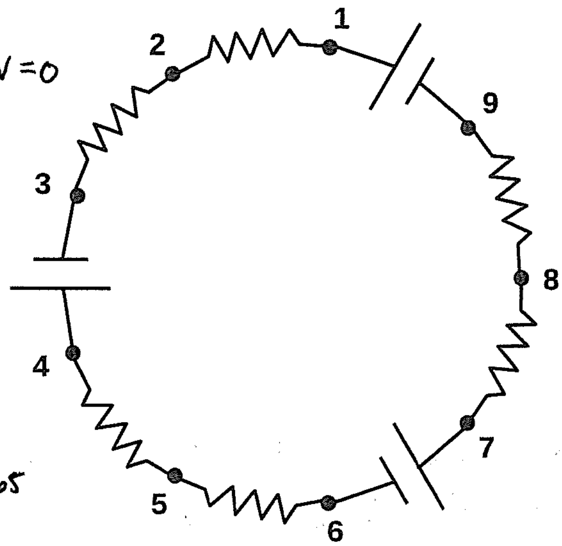
$= V$

c) $V_5 - V_8 = \Delta V_{85} = \Delta V_{87} + \Delta V_{76} + \Delta V_{65}$

$= IR - V + IR$

$= \frac{V}{2} - V + \frac{V}{2}$

$= 0$



(a 5pts) The current I in the circuit is (circle one)

All

$0 \qquad \frac{2V}{R} \qquad \frac{3V}{R} \qquad \frac{V}{2R} \qquad \frac{V}{3R} \qquad \frac{6V}{R}$

(b 5pts) The potential difference $V_1 - V_3$ is (circle one)

All

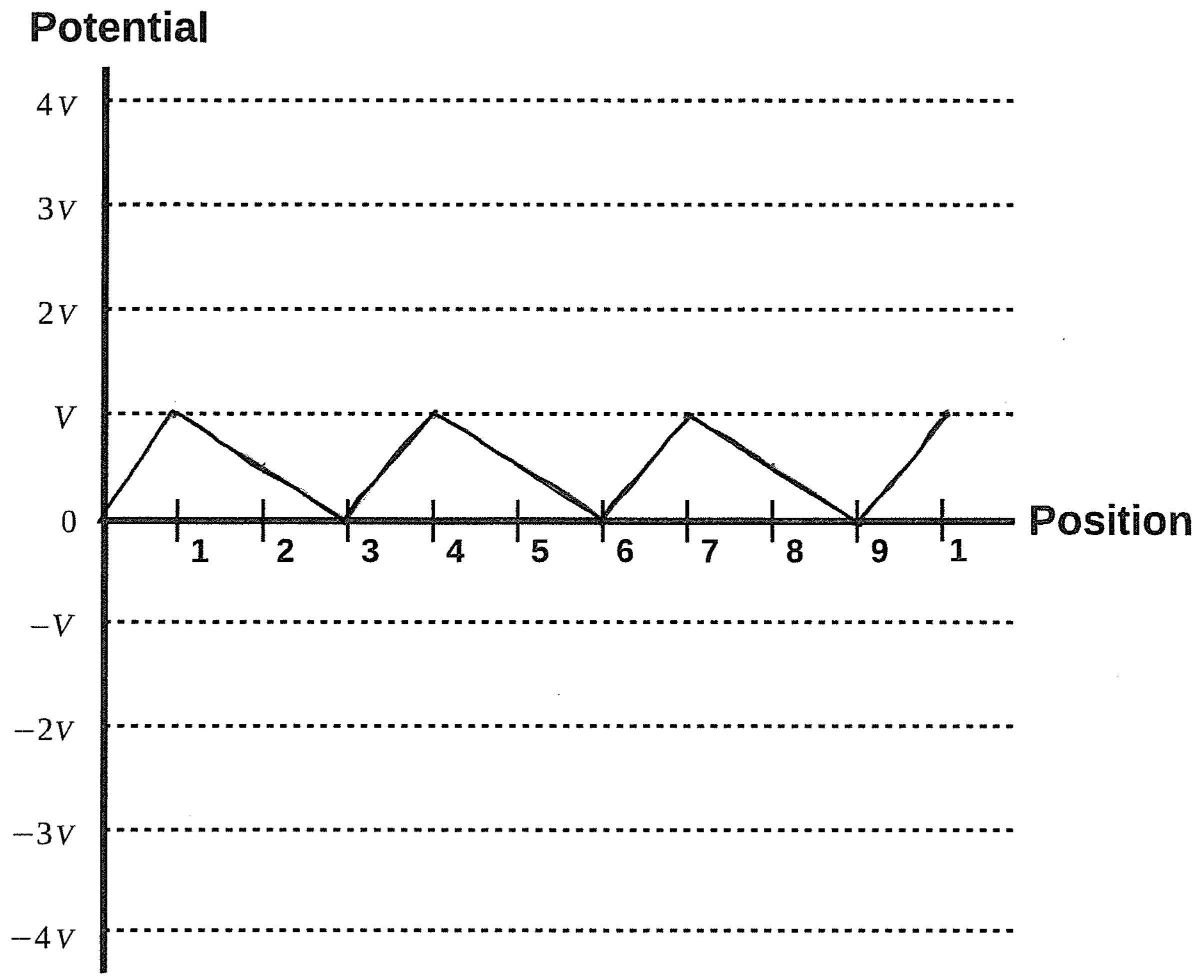
$V \qquad \frac{V}{2} \qquad 0 \qquad \frac{3V}{2} \qquad \frac{V}{3} \qquad 3V$

(c 5pts) The potential difference $V_5 - V_8$ is (circle one)

All

$V \qquad \frac{V}{2} \qquad 0 \qquad \frac{3V}{2} \qquad \frac{V}{3} \qquad 3V$

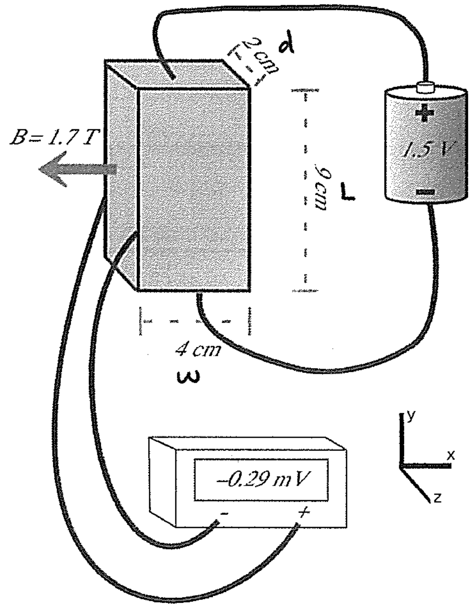
(d 10pts) On the plot below, draw an accurate graph of how the electric potential varies around the circuit.



→ TA Discuss : Note that the graph can be shifted up or down and still be correct.

Problem 3 (25 Points)

A conducting bar 9 cm long with a rectangular cross section 4 cm wide and 2 cm deep is connected to a 1.5-volt battery. This causes a constant current of 0.7 ampere to flow through the bar. The resistance of the copper connecting wires, and the internal resistance of the battery, are all negligible compared to the resistance of the bar. A uniform magnetic field of $B = < -1.7, 0, 0 >$ T is applied to the bar as shown. A voltmeter connected across the bar, with the connections carefully placed directly across from each other as shown, reads -0.29 millivolts.



(a 5pts) Inside the bar, what is the direction of the electric field $\vec{E}_{\parallel}$, due to the charges on the batteries and the surface of the wires and the bar (circle one)?

+x -x +y -y +z -z All

(b 5pts) Given that the voltmeter shows a reading of -0.29 mV, what can you conclude about the sign of the mobile charges (circle one)? HINT: recall that a voltmeter measures positive when the positive terminal of the meter is connected to a higher potential than the negative terminal.

The mobile charges are negative
The mobile charges are positive → if (a) +y } (5 pts)
The sign of the mobile charges can not be determined

(c 5pts) Determine the direction of the magnetic force on the mobile charges (circle one) → if (b) positive

All +x -x +y -y +z -z

(d 5pts) Determine the direction of the electric $\perp$ force on the mobile charges (circle one).

All +x -x +y -y +z -z → if (c) +z

(e 5pts) Calculate the mobility of the mobile charges in the bar?

$\bar{v} = u E_{\parallel} \Rightarrow u = \frac{\bar{v}}{E_{\parallel}}$ (1)

F=0 ⇒ E_{force} and B_{force} balance one another

$E_{\parallel} = \frac{\mathcal{E}mf}{L}$ (1)

$eE_{\perp} = e\bar{v}B \Rightarrow \bar{v} = \frac{E_{\perp}}{B} = \frac{\Delta V_{\perp}}{Bd}$

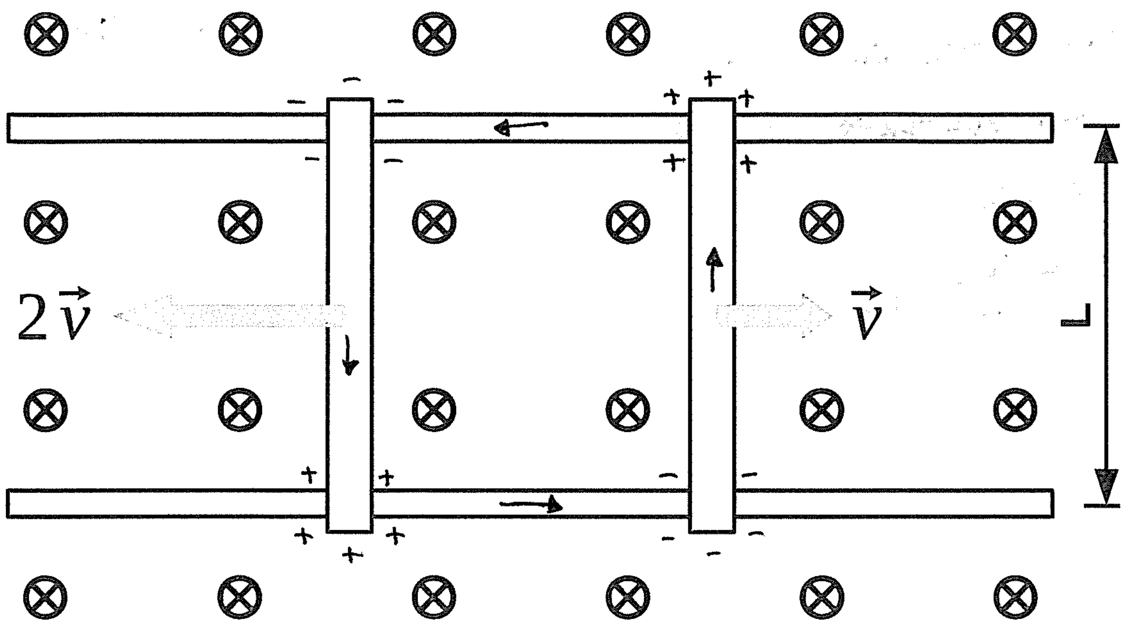
$E_{\perp} = \frac{\Delta V_{\perp}}{d}$

$= 8.5 \times 10^{-3}\ \frac{m}{s}$ (2 pt)

$$u = \frac{\bar{v}}{E_{\parallel}} = \frac{\left(\frac{\Delta V_{\perp}}{Bd}\right)}{\left(\frac{\mathcal{E}mf}{L}\right)} = \frac{\Delta V_{\perp} L}{Bd(\mathcal{E}mf)} = 5.11 \times 10^{-4}\ \frac{1}{T}\left(\frac{m/s}{V/m}\right)$$ (1)

Problem 4 (25 Points)

Two conducting rods (each with length L and resistance R) are pulled with constant speed v and $2v$ as indicated in the diagram. These rods slide, without friction, on two stationary horizontal conducting rails. A uniform magnetic field B fills all of space.



(a 5pts) On the diagram above, using 4 arrows, indicate the direction of conventional current flow. All

(b 5pts) On the diagram above, add "+" and "-" signs to indicate the electric polarization of each bar.

All ; Note if (a) is CW instead of CCW, the "+" & "-" should be reversed (c 5pts) Calculate the magnitude of the conventional current in terms of the variables given in the problem statement.

Starting @ top of right bar & moving CCW.

Note: moving Bars act like a battery. Vsing a loop rule.

$\mathcal{E}mf_L - IR + \mathcal{E}mf_R - IR = 0$ (2 pts)

$\Rightarrow 2vBL - IR + vBL - IR = 0$ (2 pts)

$\Rightarrow 3vBL = 2IR$

$\Rightarrow I = \frac{3}{2}\frac{vBL}{R}$ (1 pt)

(d 5pts) The flowing current creates a magnetic field of it's own. How does this field alter the net magnetic field in the region of space between the sliding rods (circle one)

if $I \to CW$

Increases *Decreases* *Unchanged* *Unknown*

(e 5pts) The sliding rod on the right abruptly comes to rest. After a short transient, a steady current re-establishes itself. Determine the magnitude of that steady current in terms of the variables given in the problem statement.

Again, starting @ top of right bar & moving CCW.

$\mathcal{E}mf_L - IR - IR = 0$ (2 pts)

$\Rightarrow 2vBL - 2IR = 0$ (2 pts)

$\Rightarrow 2vBL = 2IR$

$\Rightarrow I = \frac{vBL}{R}$ (1 pt)

This page is for extra work, if needed.

Things you must know

Relationship between electric field and electric force
Electric field of a point charge
Relationship between magnetic field and magnetic force
Magnetic field of a moving point charge

Conservation of charge
The Superposition Principle

Other Fundamental Concepts

$\vec{a} = \frac{d\vec{v}}{dt}$

$\Delta U_{el} = q\Delta V$

$\Phi_{el} = \int \vec{E} \bullet \hat{n} dA$

$\oint \vec{E} \bullet \hat{n} dA = \frac{\sum q_{inside}}{\epsilon_0}$

$|\text{emf}| = \oint \vec{E}_{NC} \bullet d\vec{l} = \left|\frac{d\Phi_{mag}}{dt}\right|$

$\oint \vec{B} \bullet d\vec{l} = \mu_0 \left[\sum I_{inside\ path} + \epsilon_0 \frac{d}{dt} \int \vec{E} \bullet \hat{n} dA\right]$

$\frac{d\vec{p}}{dt} = \vec{F}_{net}$ and $\frac{d\vec{p}}{dt} \approx m\vec{a}$ if $v << c$

$\Delta V = -\int_i^f \vec{E} \bullet d\vec{l} \approx -\sum (E_x \Delta x + E_y \Delta y + E_z \Delta z)$

$\Phi_{mag} = \int \vec{B} \bullet \hat{n} dA$

$\oint \vec{B} \bullet \hat{n} dA = 0$

$\oint \vec{B} \bullet d\vec{l} = \mu_0 \sum I_{inside\ path}$

Specific Results

$\left|\vec{E}_{dipole,axis}\right| \approx \frac{1}{4\pi\epsilon_0}\frac{2qs}{r^3}$ (on axis, $r \gg s$)

$\left|\vec{E}_{dipole,\perp}\right| \approx \frac{1}{4\pi\epsilon_0}\frac{qs}{r^3}$ (on $\perp$ axis, $r \gg s$)

$\left|\vec{E}_{rod}\right| = \frac{1}{4\pi\epsilon_0}\frac{Q}{r\sqrt{r^2 + (L/2)^2}}$ ($r \perp$ from center)

electric dipole moment $p = qs$, $\vec{p} = \alpha \vec{E}_{applied}$

$\left|\vec{E}_{rod}\right| \approx \frac{1}{4\pi\epsilon_0}\frac{2Q/L}{r}$ (if $r \ll L$)

$\left|\vec{E}_{ring}\right| = \frac{1}{4\pi\epsilon_0}\frac{qz}{(z^2 + R^2)^{3/2}}$ (z along axis)

$\left|\vec{E}_{disk}\right| = \frac{Q/A}{2\epsilon_0}\left[1 - \frac{z}{(z^2 + R^2)^{1/2}}\right]$ ($z > 0$ along axis)

$\left|\vec{E}_{disk}\right| \approx \frac{Q/A}{2\epsilon_0}\left[1 - \frac{z}{R}\right] \approx \frac{Q/A}{2\epsilon_0}$ (if $z \ll R$)

$\left|\vec{E}_{capacitor}\right| \approx \frac{Q/A}{\epsilon_0}$ ($+Q$ and $-Q$ disks)

$\left|\vec{E}_{fringe}\right| \approx \frac{Q/A}{\epsilon_0}\left(\frac{s}{2R}\right)$ just outside capacitor

$\Delta\vec{B} = \frac{\mu_0}{4\pi}\frac{I\Delta\vec{\ell} \times \hat{r}}{r^2}$ (short wire)

$\Delta\vec{F} = I\Delta\vec{l} \times \vec{B}$

$\left|\vec{B}_{wire}\right| = \frac{\mu_0}{4\pi}\frac{LI}{r\sqrt{r^2 + (L/2)^2}} \approx \frac{\mu_0}{4\pi}\frac{2I}{r}$ ($r \ll L$)

$\left|\vec{B}_{wire}\right| = \left|\vec{B}_{earth}\right| \tan\theta$

$\left|\vec{B}_{loop}\right| = \frac{\mu_0}{4\pi}\frac{2I\pi R^2}{(z^2 + R^2)^{3/2}} \approx \frac{\mu_0}{4\pi}\frac{2I\pi R^2}{z^3}$ (on axis, $z \gg R$) $\mu = IA = I\pi R^2$

$\left|\vec{B}_{dipole,axis}\right| \approx \frac{\mu_0}{4\pi}\frac{2\mu}{r^3}$ (on axis, $r \gg s$)

$\left|\vec{B}_{dipole,\perp}\right| \approx \frac{\mu_0}{4\pi}\frac{\mu}{r^3}$ (on $\perp$ axis, $r \gg s$)

$\vec{E}_{rad} = \frac{1}{4\pi\epsilon_0}\frac{-q\vec{a}_\perp}{c^2 r}$

$\hat{v} = \hat{E}_{rad} \times \hat{B}_{rad}$

$\left|\vec{B}_{rad}\right| = \frac{\left|\vec{E}_{rad}\right|}{c}$

$i = nA\bar{v}$

$I = |q|\, nA\bar{v}$

$\bar{v} = uE$

$\sigma = |q|\, nu$

$J = \frac{I}{A} = \sigma E$

$R = \frac{L}{\sigma A}$

$E_{dielectric} = \frac{E_{applied}}{K}$

$\Delta V = \frac{q}{4\pi\epsilon_0}\left[\frac{1}{r_f} - \frac{1}{r_i}\right]$ due to a point charge

$I = \frac{|\Delta V|}{R}$ for an ohmic resistor (R independent of ΔV); power $= I\Delta V$

$Q = C\,|\Delta V|$

$K \approx \frac{1}{2}mv^2$ if $v \ll c$

circular motion: $\left|\frac{d\vec{p}}{dt}_{\perp}\right| = \frac{|\vec{v}|}{R}|\vec{p}| \approx \frac{mv^2}{R}$

Math Help

$$\vec{a} \times \vec{b} = \langle a_x, a_y, a_z \rangle \times \langle b_x, b_y, b_z \rangle$$

$$= (a_y\, b_z - a_z\, b_y)\hat{x} - (a_x\, b_z - a_z\, b_x)\hat{y} + (a_x\, b_y - a_y\, b_x)\hat{z}$$

$$\int \frac{dx}{x+a} = \ln(a+x) + c \quad \int \frac{dx}{(x+a)^2} = -\frac{1}{a+x} + c \quad \int \frac{dx}{(a+x)^3} = -\frac{1}{2(a+x)^2} + c$$

$$\int a\,dx = ax + c \quad \int ax\,dx = \frac{a}{2}x^2 + c \quad \int ax^2\,dx = \frac{a}{3}x^3 + c$$

Constant	Symbol	Approximate Value
Speed of light	c	3×10^8 m/s
Gravitational constant	G	6.7×10^{-11} N · m^2/kg^2
Approx. grav field near Earth's surface	g	9.8 N/kg
Electron mass	m_e	9×10^{-31} kg
Proton mass	m_p	1.7×10^{-27} kg
Neutron mass	m_n	1.7×10^{-27} kg
Electric constant	$\frac{1}{4\pi\epsilon_0}$	9×10^9 N · m^2/C^2
Epsilon-zero	ϵ_0	8.85×10^{-12} (N · m^2/C^2)$^{-1}$
Magnetic constant	$\frac{\mu_0}{4\pi}$	1×10^{-7} T · m/A
Mu-zero	μ_0	$4\pi \times 10^{-7}$ T · m/A
Proton charge	e	1.6×10^{-19} C
Electron volt	1 eV	1.6×10^{-19} J
Avogadro's number	N_A	6.02×10^{23} molecules/mole
Atomic radius	R_a	$\approx 1 \times 10^{-10}$ m
Proton radius	R_p	$\approx 1 \times 10^{-15}$ m
E to ionize air	E_{ionize}	$\approx 3 \times 10^6$ V/m
B_{Earth} (horizontal component)	B_{Earth}	$\approx 2 \times 10^{-5}$ T