PHYS 2212 Test 1
Spring 2015

Name(print) Buzz Lightyear Lab Section Toy Box

Lab section by day and time: Kim(P), Ballantyne(Q)				
Monday	1:05-3:55pm	P01 or Q01	4:05-6:55pm	Q02 or P02
Tuesday	12:05-2:55pm	Q03 or P03	3:05-5:55pm	Q04 or P04
Wednesday	1:05-3:55pm	Q05 or P05	4:05-6:55pm	Q06 or P06
Thursday	12:05-2:55pm	Q07 or P07	3:05-5:55pm	Q08 or P08

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."

____

Sign your name on the line above

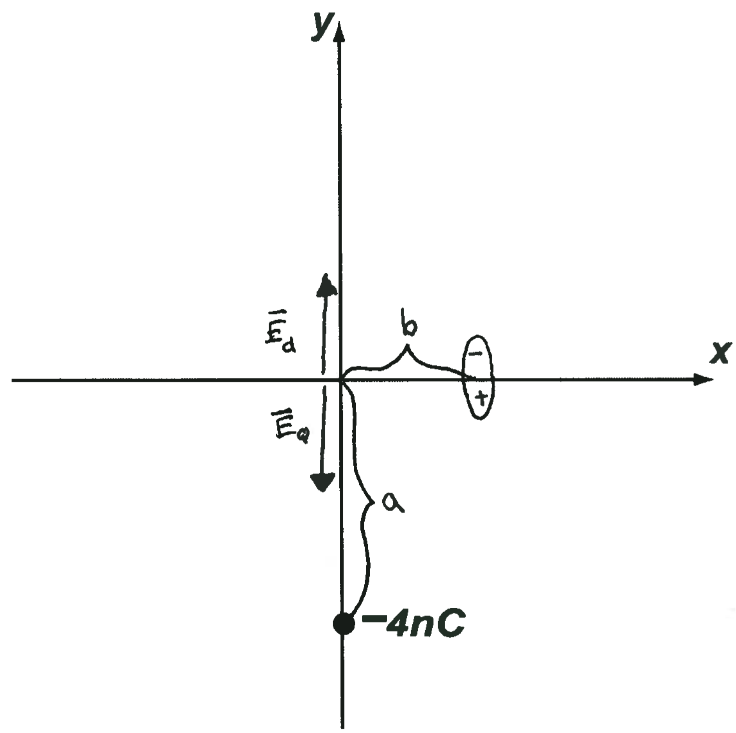
PHYS 2212

Please do not write on this page.

Problem	Score	Grader
Problem 1 (20 pts)		
Problem 2 (25 pts)		
Problem 3 (30 pts)		
Problem 4 (25 pts)		

Problem 1 (20 Points)

A hollow plastic ball with radius 1.8 cm has a charge of -4 nC spread uniformly over its surface. The center of the ball is located at $\langle 0, -8, 0 \rangle$ cm. ***Note that the diagram is not to scale.***



(a 5pts) On the diagram draw an arrow to represent the electric field vector at the origin due to the charged ball. Label it $\vec{E}_Q$. All

(b 5pts) You are asked to place a dipole at < 0.12, 0, 0 > m. On the diagram, show how you would orient this dipole so that the net field at the origin is zero. All but based on arrow for (c)

(c 5pts) On the diagram, draw an arrow to represent the electric field at the origin due to the dipole and label it $\vec{E}_d$. ***The relative lengths of the two arrows representing $\vec{E}_Q$ and $\vec{E}_d$ must be correct. Arrows without labels will be counted wrong.*** All

(d 5pts) If the dipole charges are +6e-7 C and -6e-7 C, determine the dipole separation. You can assume that the the dipole separation is much smaller than 12 cm.

$b >> s$

$$\bar{E}_{net} = 0 = \bar{E}_{dipole} + \bar{E}_{ball}$$

$$\Rightarrow |\bar{E}_{dipole}| = |\bar{E}_{ball}|$$

$$\Rightarrow \frac{1}{4\pi\epsilon_0} \frac{qs}{b^3} = \frac{1}{4\pi\epsilon_0} \frac{|Q|}{a^2}$$

$$\Rightarrow s = \frac{|Q|}{q} \frac{b^3}{a^2} = 0.0018\,m = 1.8\,mm$$

→ 5pts correct
→ 3pts if they used 2qs
→ 0pts otherwise

Problem 2 (25 Points)

A small, very lightweight hollow aluminum ball is suspended from a cotton thread. The events depicted in frames 1-6 then occur, in sequence. All diagrams show cross-sectional views of the objects.

(a 16pts) For frames 1, 3, and 5-6 below, write the letter of the corresponding diagram (A-P) that best depicts the distribution of charge in and/or on the aluminum ball, following the conventions for diagrams discussed in the textbook and in class. Some letters may be used more than once; others may not be used at all.

4 pts each

→ if A I J J then 12 pts

1. The charged ball is initially far away from any objects.

Diagram B

2. The ball is brought close to an uncharged copper block (without touching)

3. The ball swings toward the block

Diagram G

4. The ball briefly touches the block.

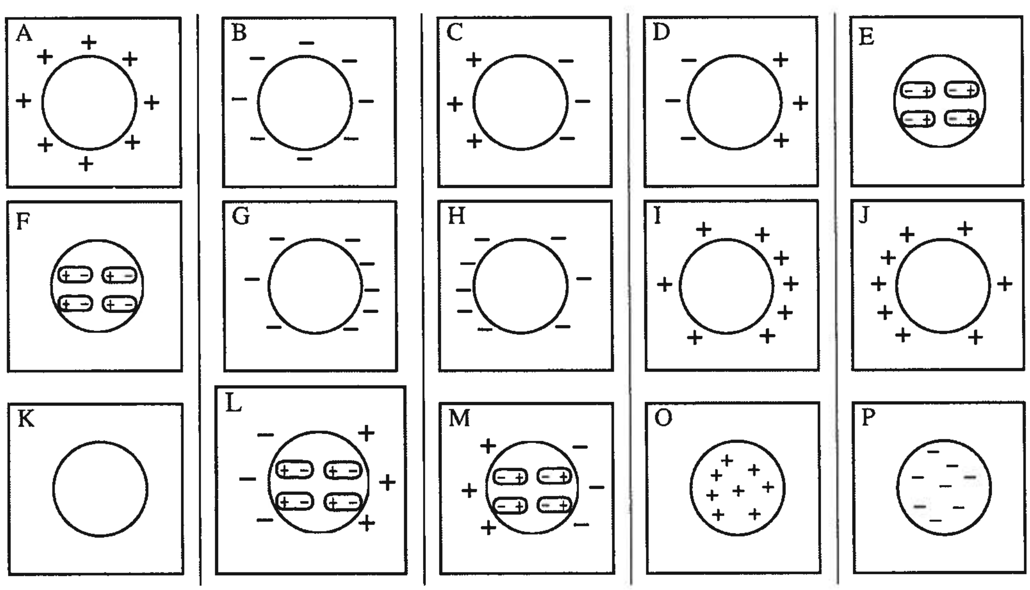
5. The ball swings away from the block and after a short while hangs at an angle of about 10 degrees

Diagram H

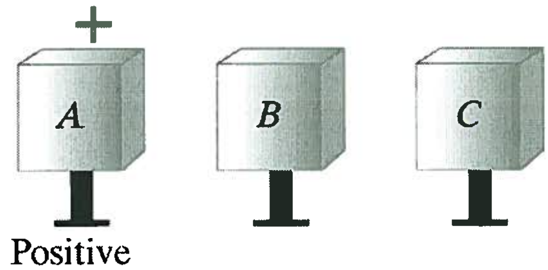
6. A negatively charged plastic pen is brought near the ball and the ball is repelled.

Diagram H

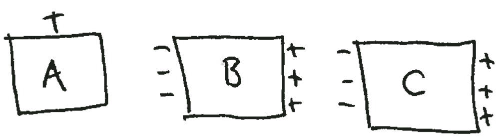
Diagrams showing distribution of charge in and/or on the aluminum ball.



(b 4pts) You have three metal blocks marked A, B, and C, sitting on insulating stands. All three blocks are free to move. Block A is charged +, but blocks B and C are neutral. Without using any additional equipment, and without altering the amount of charge on block A, explain how you could make block C be negatively charged. Explain your procedure in detail, including diagrams of the charge distributions at each step in the process.



1)

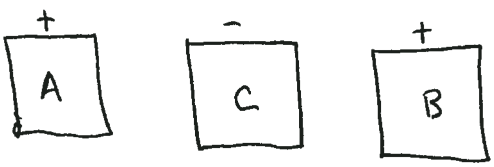


(initial)

2)

Place block C in middle. Bring block B &C into contact.

3)



After a short time, seperate blocks B &C. Then block C will have negative charge.

All

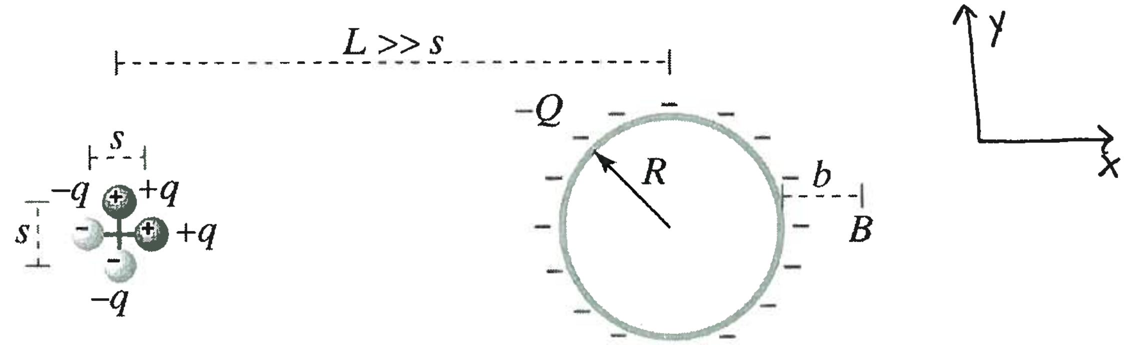
(c 5pts) Explain briefly why the attraction between a point charge and a dipole has a different distance dependence for induced dipoles $(1/r^5)$ than for permanent dipoles $(1/r^3)$.

Induced dipoles are caused by polarization. Since, the polarization is proportional to the external field the induced dipole field will scale with the external field too. Permanent dipoles do not acquire a polarization. This is the source of the difference in the distance dependence.

All

Problem 3 (30 Points)

A thin, hollow spherical plastic shell of radius R carries a uniformly distributed negative charge $-Q$. A slice through the plastic shell is shown in the diagram. To the left of the spherical shell are four charges packed closely together as shown (the distance s is shown greatly enlarged for clarity). The distance from the center of the four charges to the center of the plastic shell is L, which is much larger than s ($L >> s$).



(Greatly enlarged) Thin plastic shell

(a 10pts) Calculate the net electric field at location B, a distance b to the **right** of the outer surface of the plastic shell.

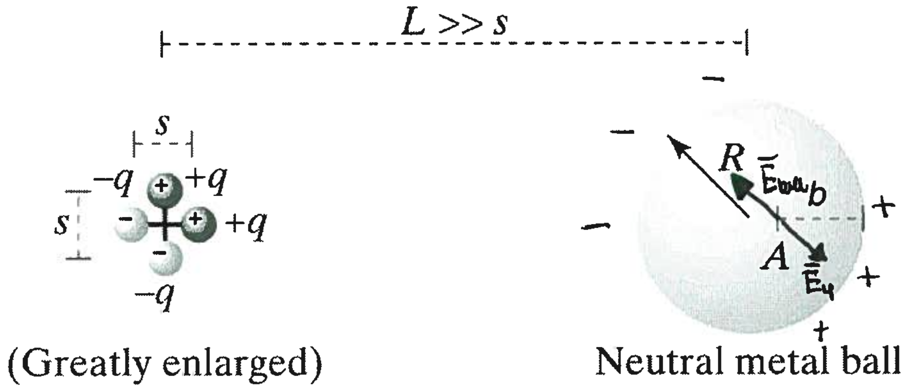
Since $L >> s$ use approximate formula's for a dipole.

$$\bar{E}_{net @ B} = \bar{E}_{shell} + \bar{E}_{dipole,\parallel} + \bar{E}_{dipole,\perp}$$

$$= \left[-\frac{1}{4\pi\epsilon_0} \frac{Q}{(R+b)^2} + \frac{1}{4\pi\epsilon_0} \frac{2qs}{(L+R+b)^3} \right] \hat{x} - \left[\frac{1}{4\pi\epsilon_0} \frac{qs}{(L+R+b)^3} \right] \hat{y}$$

−0.5
−1.5
−3.0
−8.0

The plastic shell is removed and replaced by a solid neutral metal ball of radius R as seen in the diagram. The distance from the center of the four charges to the center of the plastic shell is L, which is much larger than s ($L >> s$).



5pts each

(b 10pts) At location A inside the metal ball, a distance b to the **left** of the outer surface of the ball, accurately draw and label the electric fields due to the collection of four charges E_4 and the polarization of the ball E_{ball}. If any of these quantities are zero please state this explicitly.

(c 5pts) On the diagram, draw the charge distribution on the ball. All or −1 for unequal #

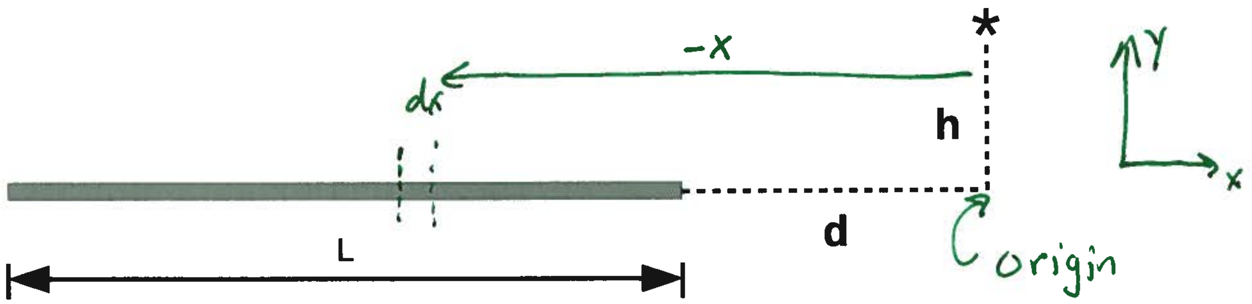
(d 5pts) Calculate the net electric field at location A. Briefly explain how you determined this.

$\bar{E}_{net\,@A} = 0$ $\qquad$ $\bar{E} = 0$ inside a conductor $\qquad$ All

polarization of ball is such that it cancels the external E-field.

Problem 4 (25 Points)

A very thin plastic rod of length L is rubbed with cloth and becomes uniformly charged with a total charge $-Q$.



(a 20pts) Determine the electric field $d\vec{E}$ from an arbitrary piece of the rod at observation location "$*$", a distance d to the right of the end of the rod and a distance h above the rod as indicated in the diagram. On the diagram, indicate the location of your choice of origin and the direction of the positive x and y axis.

$\vec{r}_{OBS} = \langle 0, h, 0 \rangle \qquad \vec{r}_{source} = \langle -x, 0, 0 \rangle$

$\vec{r} = \langle x, h, 0 \rangle \qquad \rho = \frac{-Q}{L} \Rightarrow dQ = \rho\, dx$

$= -\frac{Q}{L} dx$

$d\vec{E} = \frac{1}{4\pi\epsilon_0} \frac{dQ}{|\vec{r}|^2} \hat{r}$

$= \frac{1}{4\pi\epsilon_0} \left(\frac{-Q}{L}\right) \frac{\langle x, h, 0 \rangle}{(x^2+h^2)^{3/2}} dx$

-1.0
-3.0
-6.0
-16.0

(b 5pts) Write down the integral you would solve to determine the net electric field $\vec{E}$ of the rod at location "$_*$". You do not need to solve this integral but you must explicitly state the integration variable and the limits of integration consistent with part (a).

$$\vec{E}_{rod} = \frac{-Q}{4\pi\epsilon_0 L}\int_{+(L+d)}^{+d} \frac{\langle x, h, 0\rangle}{(x^2+h^2)^{3/2}}\,dx$$

→ Answer a vector (1pt)

→ limits match choices from (a) (2pts)

→ $\vec{E}_{rod} = \int d\vec{E}$ (2pts)

(Extra Credit 5pts) Calculate the x-component of the net electric field E_x of the rod at location "$_*$".

$$E_x = \frac{-Q}{4\pi\epsilon_0 L}\int_{+(L+d)}^{+d} \frac{x}{(x^2+h^2)^{3/2}}\,dx$$

let $u = x^2+h^2$

$du = 2x\,dx$

$$E_x = \frac{-q}{4\pi\epsilon_0 L}\int_{(L+d)^2+h^2}^{d^2+h^2} \frac{1}{2}\frac{du}{u^{3/2}} = -\frac{Q}{4\pi\epsilon_0 L}\,u^{-1/2}\Bigg|_{(L+d)^2+h^2}^{d^2+h^2}$$

$$E_x = \frac{-Q}{4\pi\epsilon_0 L}\left(\frac{1}{(d^2+h^2)^{1/2}} - \frac{1}{((L+d)^2+h^2)^{1/2}}\right)$$

All

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

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

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

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

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

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

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

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

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

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

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

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

Specific Results

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

$\mu = IA = I\pi R^2$

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

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

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

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

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

$i = nA\bar{v}$

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

$\bar{v} = uE$

$\sigma = |q|\,nu$

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

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

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

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

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

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

$\text{K} \approx \frac{1}{2}mv^2$ 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