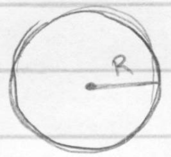
Physics 2b Final Solutions #1 p.1

Uniformly charged sphere, $R = 0.3m$

$E(0.5m) = 15,000 N/C$

$\vec{E} = 15,000 N/C\ \hat{r}$



By Gauss's law we know that, for $r > R$

$$\vec{E}(r) = \frac{KQ}{r^2}\hat{r}$$

$$\Rightarrow 15,000 N/C = \frac{\left(9\times10^9 \frac{Nm^2}{C^2}\right)Q}{(0.5m)^2} \Rightarrow Q = 4.17\times10^{-7}C$$

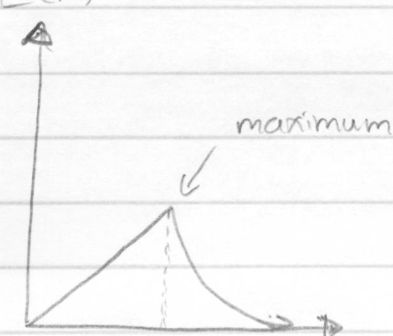
We also know that the Electric field is a maximum for $r = R$ (at the surface), so

$$\vec{E}(0.3m) = \frac{\left(9\times10^9 \frac{Nm^2}{C^2}\right)\left(4.17\times10^{-7}C\right)}{(0.3m)^2}\hat{r}$$

$$= 4.17\times10^4 N/C\ \hat{r}$$

is the maximum field. $\Rightarrow \boxed{42,000 N/C}$

Note: $E(r)$

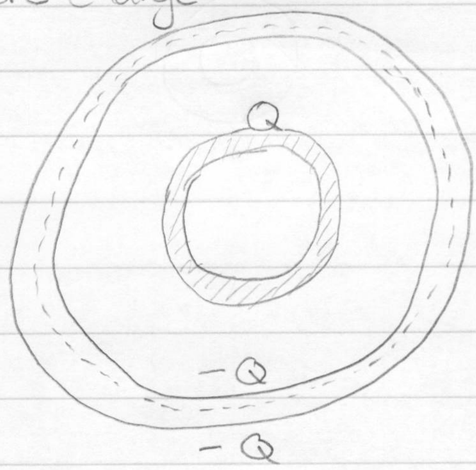


Physics 2b Final Solutions #2 p.1

three hollow concentric conducting spheres

inner sphere charge +Q

second sphere charge -2Q



I've only drawn the first two

What is the charge on the outer surface of sphere 2?

We know that in electrostatic equilibrium, the $\vec{E}$ field inside a conductor must be zero. If we choose the Gaussian surface given by the dashed line, that tells us

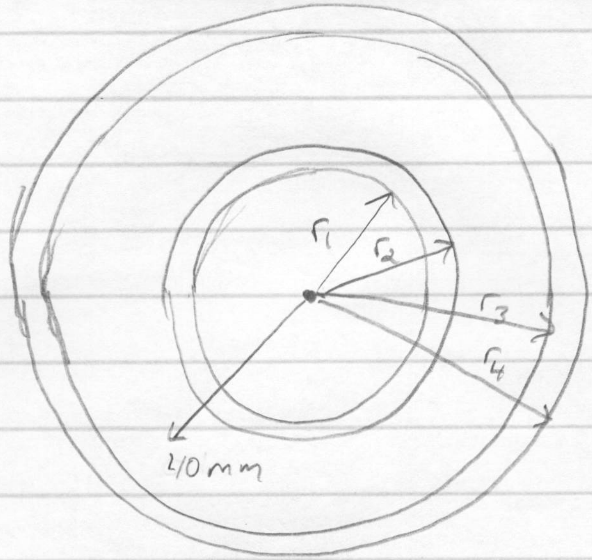
$$\oint \vec{E} \cdot d\vec{A} = q_{enc}/\varepsilon_0$$

but we know $\vec{E}$ is $0 \Rightarrow \oint \vec{E} \cdot d\vec{A} = 0 \Rightarrow q_{enc} = 0$

q_{enc} = charge on sphere one + inner surface of sphere 2

$\Rightarrow$ sphere 2's inner surface must have $-Q$

Since the total charge of sphere 2 is given as $-2Q$, the other $\boxed{-Q}$ must be on the outer surface. Because of symmetry, the charge on the third sphere is irrelevant.



$r_1 = 28mm$
$r_2 = 30mm$
$r_3 = 49mm$
$r_4 = 51mm$

coaxial cable, $\lambda_1 = -30\,nC/m$, $\lambda_2 = -50\,nC/m$

What is $E_r(40mm)$?

By Gauss's law, we have $\vec{E}(r) = \dfrac{\lambda}{2\pi\varepsilon_0 r}\hat{r}$

40 mm is between the inner and outer conductor, so $\lambda = \lambda_1$ and

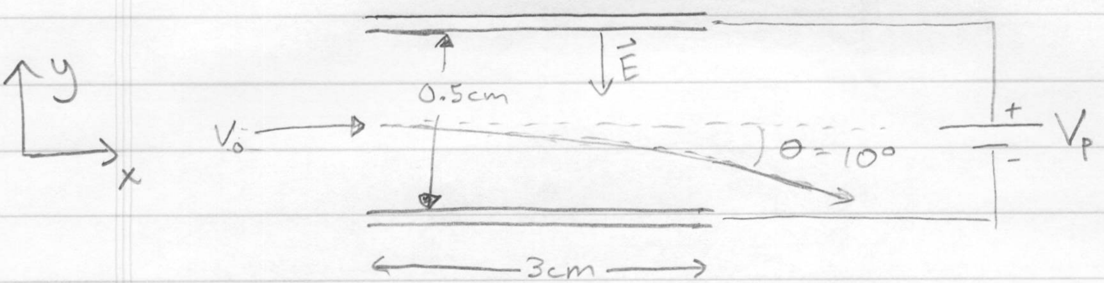
$$\vec{E}(r) = \frac{-30\times10^{-9}\,C/m}{2\pi(8.85\times10^{-12}\,C^2/Nm^2)(40\times10^{-3}\,m)}\hat{r}$$

$$= -13{,}487\,N/C\,\hat{r}$$

$$\Rightarrow \boxed{-14{,}000\,N/C}$$

Note, for $r > r_4 = 51mm$, we would have to use $\lambda = \lambda_1 + \lambda_2$ to get the charge enclosed by the gaussian surface.

Physics 2b Final Solutions # 4 p.1



charged particle, $\Delta V_{acc} = 15{,}000\,V$ accelerating voltage, deflected by charged plates, what V_p to get $\theta = 10°$?

First, we must find the speed at which the particle enters the region. Conservation of Energy tells us

$\Delta U = \Delta KE \Rightarrow$

$q\Delta V_{acc} = \frac{1}{2} m v_0^2 \Rightarrow v_0 = \sqrt{\frac{2q\Delta V_{acc}}{m}}$

Notice that V_p only acts on the particle in the y-direction, so the time taken to cross the plates is given by $t_f = \frac{l}{v_0}$, where $l = 3cm$.

While it is between the plates, the particle is accelerated in the y-direction $a_y = \frac{F}{m} = \frac{qE}{m}$

and E is related to V_p by $V_p = Ed$, $d = 0.5cm$.

Finally, the y-velocity starts at zero and is

$v_y = a_y t$ at any time t.

We want a deflection $\tan\theta = \frac{v_y}{v_0}$, $\theta = 10°$.

Putting it all together: $V_p = Ed = \frac{m a_y}{q} d = \frac{m\left(\frac{v_y}{t}\right)}{q} d = \frac{m \tan\theta\, v_0\, d}{\left(\frac{l}{v_0}\right) q}$

$= \frac{\cancel{m} \tan\theta}{l \cancel{q}} \frac{2\cancel{q}\Delta V_{acc}}{\cancel{m}} d = \frac{\tan(10°)\, 2(15000\,V)(0.5\times10^{-2}m)}{3\times10^{-2}m} = \boxed{882V}$

Physics 2b Final Solutions #5 p.1

$V_{ab} = 100V$, what is U?

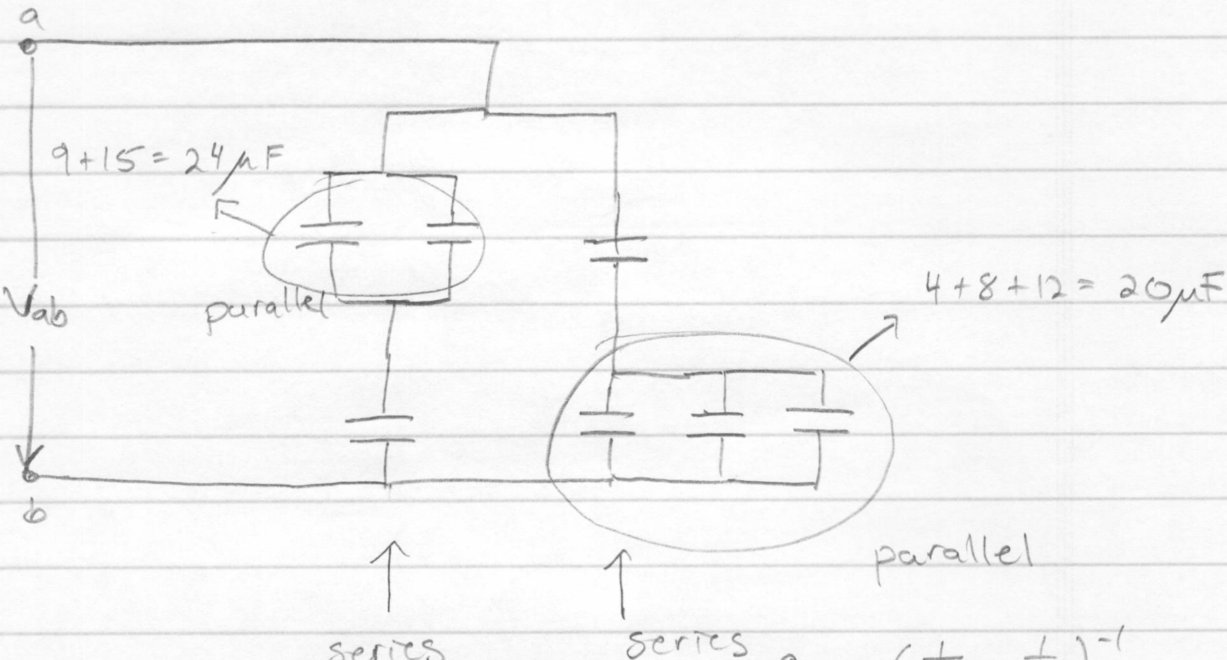
To solve this problem we will find the equivalent capacitance of the entire circuit and then use $U = \frac{1}{2}CV^2$.

Recall: series

$$\frac{1}{C} = \sum_i \frac{1}{C_i}$$

parallel

$$C = \sum_i C_i$$



$$C_1 = \left(\frac{1}{24} + \frac{1}{16}\right)^{-1} = 9.6\mu F$$

$$C_2 = \left(\frac{1}{20} + \frac{1}{6}\right)^{-1} = 4.62\mu F$$

parallel

$$C_{tot} = 9.6 + 4.62 = 14.22\mu F$$

$$U = \frac{1}{2}CV^2 = \frac{1}{2}(14.22\mu F)(100V)^2 = 71mJ \Rightarrow \boxed{72mJ}$$

Physics 2b Final Solutions # 6

capacitor, connected to battery, dielectric inserted

what happens ?

$C_0 \to C = KC_0$

$V_0 \to V = V_0$

$Q_0 \to Q = (KC_0)V_0 = KQ_0 \Rightarrow$ $\boxed{\text{charge increased}}$

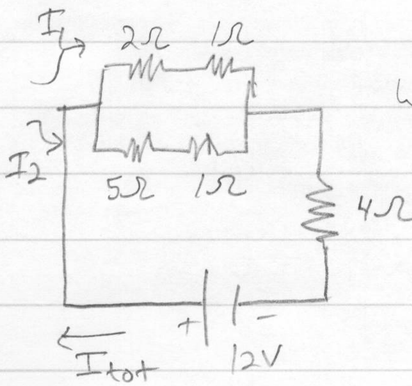
$U_0 \to U = \frac{1}{2}(KC_0)V_0^2 = KU_0$

Note, the energy <u>increased</u>

the charge <u>does</u> change

the voltage <u>stays the same</u>.

7.



What is P of 2Ω?

$R_{eff} = 4\Omega + \left(\frac{1}{(2+1)\Omega} + \frac{1}{(5+1)\Omega}\right)^{-1}$

$= 6\Omega$

$I_{tot} = \frac{V}{R_{eff}} = \frac{12V}{6\Omega} = 2A$

Voltage across elements in parallel must be equal

$\Rightarrow I_1(2\Omega + 1\Omega) = I_2(5\Omega + 1\Omega)$

but we also have $I_{tot} = I_1 + I_2 \Rightarrow I_2 = 2A - I_1$

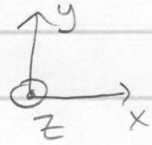
$I_1(3\Omega) = (2A - I_1)(6\Omega)$

$\frac{I_1}{2} = 2A - I_1 \Rightarrow \frac{3}{2}I_1 = 2A \Rightarrow I_1 = 4/3\,A$

Finally, $P = I^2R = (4/3\,A)^2(2\Omega) = \boxed{3.56\ W}$

Physics 2b Final Solutions #8

$\otimes \vec{B} = 0.80\,T\,(-\hat{k})$



$\uparrow \vec{E} = 12{,}000\,V/m\ \hat{j}$

$\longrightarrow V_0 = 1.5 \times 10^4\,m/s\ \hat{\imath}$

Note that both $\vec{v} \times \vec{B}$ and $\vec{E}$ are in the $\hat{j}$ direction,

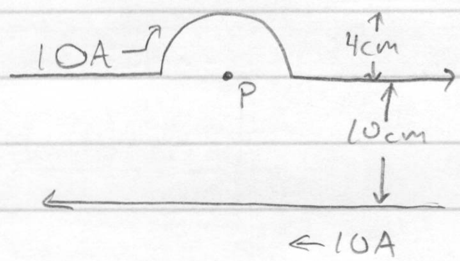
so $F_y = qvB + qE = q(vB + E)$

$= (-1.6 \times 10^{-9}\,C)(1.5 \times 10^4\,m/s\ 0.8\,T + 12{,}000\,V/m)$

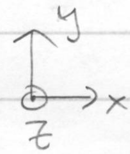
$= -3.84 \times 10^{-15}\,N$

$\Rightarrow \boxed{-4 \times 10^{-15}\,N}$

#9 "



what is B(P)?



Use superposition:

$\vec{B}_{tot} = \vec{B}_{semicircle} + \vec{B}_{line}$

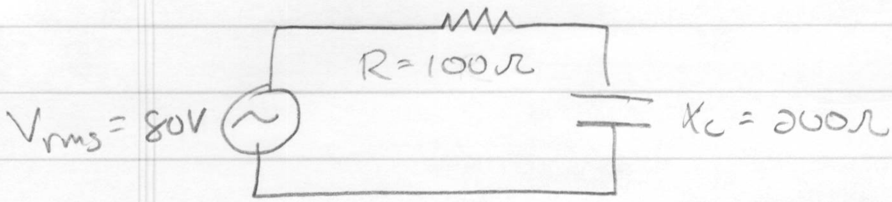
$$= \left(\frac{\mu_0 I_1}{4a} + \frac{\mu_0 I_2}{2\pi y} \right) (-\hat{k})$$

$$= \left(\frac{\mu_0 (10A)}{4(4 \times 10^{-2} m)} + \frac{\mu_0 (10A)}{2\pi (10 \times 10^{-2} m)} \right) (-\hat{k}) = -9.88 \times 10^{-5}\,T\,\hat{k}$$

$\Rightarrow \boxed{100\,\mu T}$

Note they are both in the $(-\hat{k})$ direction by the right hand rule, and the answer asks for the magnitude.

Physics 2b Final Solutions # 10



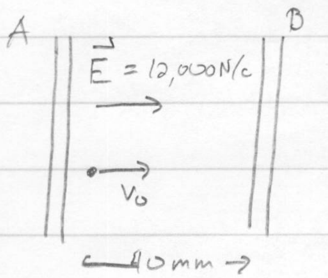
$$I_{rms} = \frac{V_{rms}}{Z}, \quad Z = \sqrt{R^2 + X_C^2}$$

$$V^C_{Rms} = I_{rms} X_C = \frac{V_{rms} X_C}{\sqrt{R^2 + X_C^2}} = \frac{(80V)(200\Omega)}{\sqrt{(100\Omega)^2 + (200\Omega)^2}}$$

$$= 71.55\,V$$

$$\Rightarrow \boxed{72V}$$

11



What is v @ B?

$V_0 = 2.0 \times 10^7\,m/s$

Notice that the e^- will be decelerated by $\vec{E}$ and energy will be conserved.

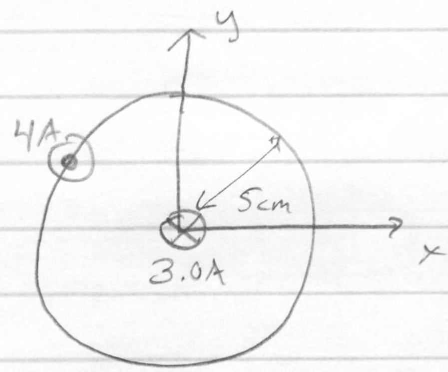
$$\Delta U = q\Delta V = qEd$$
$$\Delta KE = \tfrac{1}{2}mv^2 - \tfrac{1}{2}mv_0^2$$

$$\Rightarrow \tfrac{1}{2}mv^2 = \tfrac{1}{2}mv_0^2 + qEd$$

$$v = \sqrt{v_0^2 + \frac{2qEd}{m}} = \sqrt{(2\times10^7\,m/s)^2 + \frac{2(-e)(12{,}000\,N/C)(40mm)}{9.11\times10^{-31}\,Kg}}$$

$$= \boxed{1.52 \times 10^7\,m/s}$$

Physics 2b Final Solutions # 12



What is B_y @ $x = 3cm$?

Note that on the x-axis, the $\vec{B}$ field has <u>only</u> a y component, so $|\vec{B}| = B_y$. From Ampere's law we have $B = \frac{\mu_0 I}{2\pi r}$ and becaue

we are inside the outer shell, $I = 3A$

$$B_y = \frac{\mu_0 (3A)}{2\pi (3\times10^{-2} m)} = 2\times10^{-5} T$$

By the right hand rule, the direction is $(-\hat{j})$.

$$\Rightarrow \boxed{-20\times10^{-6} T}$$