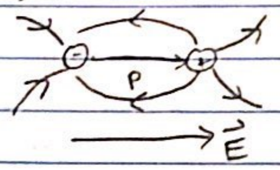
Physics 1B HW #6

21.53) $\boxed{\theta = 180, 0^\circ}$

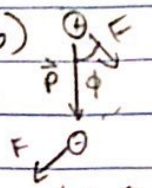
b) $\vec{p} \parallel \vec{E}$ is stable

$\boxed{\text{same direction}}$

c)



b)



$\phi = 0.723$ rads

$\phi = 41.4^\circ$

$\boxed{-90^\circ}$

c) $\tau = pE\sin\phi$

$\tau = qE(d\sin\phi)$

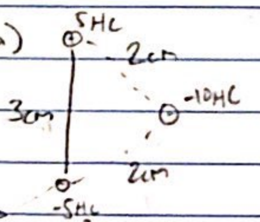
$\tau = (5\times10^{-6}C)(E)(0.03m\sin(41.4))$

$E = \frac{F}{q} = \frac{2250N}{10\times10^{-6}C} = 2.25\times10^{8}\,N/c$

$\boxed{\tau = 22.3Nm}$

d) $\boxed{\text{clockwise}}$

21.55) a)



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

$|F| = 2qE$

$E = \frac{1}{4\pi\varepsilon_0}\left(\frac{q}{r^2}\right)$

$= 9\times10^{9}\,N\frac{m^2}{C^2}\left(\frac{10\times10^{-6}C}{0.02^2m^2}\right)$

$|\vec{E}| = 2.25\times10^{8}\,N/c$

$|\vec{F}| = (2)(5\times10^{-6}c)(2.25\times10^{8}N/c)$

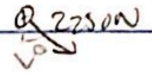
$|F| = 2250N$ X

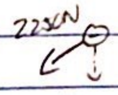
$\vec{F} = k\frac{q_1q_2}{r^2}$

$\vec{F}_1 = \vec{F}_2 \therefore F_{tot} = 2k\frac{q_1q_2}{r^2}$

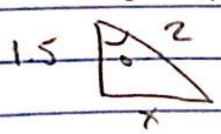
$\vec{F}_{tot} = 2(9\times10^{9}N\frac{m^2}{C^2})\left(\frac{10\times5}{(0.02m)^2}\right)(10^{-12})$ X

$|F| = 2250N$





only vertical components matter



$\cos\theta = \frac{1.5}{2} = \frac{3}{4}$

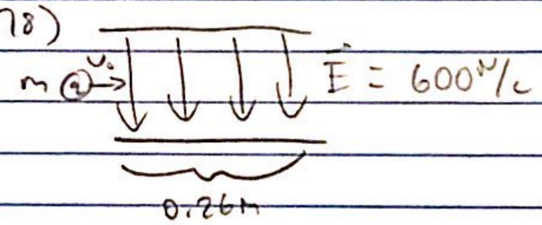
$\theta = 0.723$ rads

$|\vec{F}_y| = |F|\cos\theta$

~~$|\vec{F}_y| = 1488.18N$~~

$\boxed{|F_y| = 1690N}$

21.78)



$v_0 = 4\times10^{3}\frac{m}{s}$

$t_{in} = \frac{d}{v} = \frac{0.26m}{4.00\times10^{3}\frac{m}{s}}$

$t_{in} = 6.5\times10^{-5}s$

$E = \frac{F}{q} = \frac{ma}{q}$

$qE = ma$

$\frac{q}{m} = \frac{a}{E}$

$\Delta d = 0.0135m,\ \Delta d = \Delta d_{in} + \Delta d_{out}$

$\Delta d_{out} = v_y t$

$t_{out} = \frac{d}{v} = \frac{0.56m}{4.00\times10^{3}\frac{m}{s}} = 1.4\times10^{-4}s$

$\Delta d_{out} = v_y(1.4\times10^{-4}s)$

$\Delta d_{in} = \frac{1}{2}at_{in}^2 = a(4.225\times10^{-9}s^2)$

$0.0135m = a(4.225\times10^{-9}s^2) + v_y(1.4\times10^{-4}s)$

$v_y = at_{in} = a(6.5\times10^{-5}s)$

$0.0135m = a(1.3325\times10^{-8}s^2)$

$a = 1.01\times10^{6}\frac{m}{s^2}$

$q/m = 1688.56\,C/kg$ X

$\Delta d = \Delta d_{in} + \Delta d_{out}$

$\Delta d_{in} = \frac{1}{2} a t_{in}^2$

$\Delta d_{out} = v_y t_{out}$

$t_{in} = \frac{d_{in}}{v_x} = \frac{0.26m}{4000\frac{m}{s}}$

$t_{in} = 6.5\times10^{-5} s$

$t_{out} = \frac{d_{out}}{v_x} = \frac{0.56m}{4000\frac{m}{s}}$

$t_{out} = 1.4\times10^{-4} s$

$\Delta d_{in} = \frac{1}{2} a (6.5\times10^{-5} s)^2$

$\Delta d_{in} = (2.1125\times10^{-9} s^2) a$

$\Delta d_{out} = (1.4\times10^{-4} s) v_y$

$v_y = a t_{in} = a(6.5\times10^{-5} s)$

$\Delta d_{out} = 9.1\times10^{-9} s^2 (a)$

$0.0135m = a(2.1125\times10^{-9} s^2 + 9.1\times10^{-9} s^2)$

$a = 1.204\times10^{6} \frac{m}{s^2}$

$F = qE$

$ma = qE$

$\frac{q}{m} = \frac{a}{E}$

$\boxed{\frac{q}{m} = 2006.69 \, C/kg}$

21.84) a)

y-components cancel

$\vec{E}$ is directed right -> +x

$\vec{E} = \frac{F}{q}$

$F = k\frac{q_1 q_2}{r^2}$

$E = \frac{kQ}{a^2}$ X

$\lambda = \frac{Q}{L}$

$E = \int dE_y = \int dE \sin\theta$

$dE = \frac{k\,dq}{r^2} = \frac{k\,dq}{a^2}$

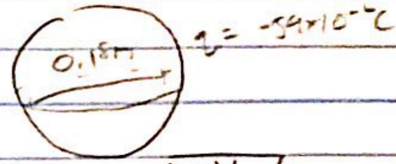
$E = \int \frac{k\,dq}{a^2} \sin\theta$

$\lambda = \frac{dq}{a\,d\theta} \rightarrow dQ = a\lambda$

$E = \int_0^{\pi} \frac{ka\lambda}{a^2} \sin\theta\, d\theta = \frac{k\lambda}{a}\int_0^{\pi} \sin\theta$

$E = \frac{2k\lambda}{a} = \boxed{\frac{4kQ}{\pi a^2}}$

22.7)



a) inside -> $\boxed{0 \frac{N}{C}}$

b) $E = k\left(\frac{q}{r^2}\right)$

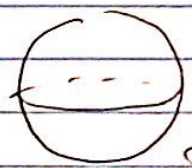
$\vec{E} = (9\times10^9 N\frac{m^2}{C^2})\left(\frac{-59\times10^{-6}C}{0.09m^2}\right)$

$\boxed{E = -6.56\times10^{7} N/C}$

c) $\vec{E} = (9\times10^9 N\frac{m^2}{C^2})\left(\frac{-59\times10^{-6}C}{(0.09+0.06m)^2}\right)$

$\boxed{\vec{E} = -2.36\times10^{7} N/C}$

22.19)



$r_o = 0.26m$

$r_i = 0.2m$

$\sigma_o = 6.17\times10^{-6} \frac{C}{m^2}$

a) $Q_{tot} = Q_i - Q_{new}$

$Q_{total} = \sigma_o A - 0.4\mu C$

$A = 4\pi r_o^2 = 0.849 m^2$

$Q_{tot} = 4.84\times10^{-6} C$

$\sigma = \frac{Q_{tot}}{A} = \boxed{5.7\times10^{-6} \frac{C}{m^2}}$

b) $\vec{E} = k\left(\frac{Q_{tot}}{r^2}\right)$

$\vec{E} = (9\times10^9 N\frac{m^2}{C^2})\left(\frac{4.84\times10^{-6}C}{0.26m^2}\right)$

$\boxed{\vec{E} = 6.44\times10^{5} N/C}$

c) $\Phi = \frac{Q_{tot}}{\varepsilon_0}$

$\Phi = \frac{-0.4\times10^{-6}C}{\varepsilon_0}$

$\boxed{\Phi = -4.52\times10^{4} N\frac{m^2}{C}}$

22.21) a) $\vec{E} = k\left(\frac{q}{r^2}\right)$

$\vec{E} = k\left(\frac{q}{(r+d)^2}\right)$

$1660\frac{N}{C} = (9\times10^9 N\frac{m^2}{C^2})\left(\frac{q}{(0.59m)^2}\right)$

$q = 4.78\times10^{-8} C$

$\rho = \frac{q}{V} = \frac{q}{\frac{4}{3}\pi r^3} =$ X

$EA = \frac{q}{\varepsilon_0}$

$q = \varepsilon_0 EA$

$\rho = \frac{q}{V} = \frac{\varepsilon_0 E(4\pi R^2)}{\frac{4}{3}\pi r^3} = \frac{3\varepsilon_0 E R^2}{r^3}$

$\boxed{\rho = 2.41\times10^{-7} C/m^3}$

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b) $E = k\frac{q}{r^2}$

$\rho = \frac{q}{V}$

$q = \rho V = \rho(\frac{4}{3}\pi r^3)$

$E = \frac{1}{4\pi\varepsilon_0}\cdot\frac{\rho(\frac{4}{3}\pi r^3)}{r^2}$

$E = \frac{\rho r}{3\varepsilon_0}$

$\boxed{E = 1750\ N/C}$

22.45) $EA = \phi$

$\phi \int \rho(r')$

$\rho(r) = \frac{\alpha}{r}$, $\partial V = 4\pi r^2 \partial r$

$\phi = \int_a^r \rho(r')\partial V' \quad 4\pi\alpha\int_a^r r'\partial r'$

$\phi = 4\pi\alpha(\frac{1}{2})(r^2 - a^2)$

$E(4\pi r^2) = 4\pi\alpha(\frac{1}{2})(r^2 - a^2)/\varepsilon_0$

$\boxed{E = \frac{\alpha}{2\varepsilon_0}(1 - \frac{a^2}{r^2})}$

b) $E_q = \frac{1}{4\pi\varepsilon_0}(\frac{q}{r^2})$

$E + E_q = \frac{\alpha}{2\varepsilon_0} - \frac{\alpha a^2}{2\varepsilon_0 r^2} + \frac{1}{4\pi\varepsilon_0}(\frac{q}{r^2})$

$+\frac{\alpha a^2}{2\varepsilon_0 r^2} = \frac{q}{2\cdot 4\pi\varepsilon_0 r^2}$

$\alpha a^2 = \frac{q}{2\pi}$

$\boxed{q = +2\pi\alpha a^2}$

c) $\boxed{\frac{\alpha}{2\varepsilon_0}}$

22.46) a) $\boxed{\text{Yes}}$

b) $F = k\frac{q_1 q_2}{r^2}\hat{r}$

$EA = \frac{q}{\varepsilon_0}$

$r < R$

$q_{encl}(r) = Q\frac{r^3}{R^3} = e\frac{r^3}{R^3}$

$F = qE$

$EA = \frac{q_{encl}}{\varepsilon_0}$

$E(\vec{r}) = \frac{e}{4\pi\varepsilon_0}(\frac{r}{R^3}) = \frac{e}{4\pi\varepsilon_0}(\frac{r}{R^3})\hat{r}$

$F = -e(\frac{e}{4\pi\varepsilon_0})(\frac{r}{R^3})\hat{r}$

$\boxed{F = \frac{-e^2 r}{4\pi\varepsilon_0 R^3}}$

c) $\boxed{\text{Yes, SHM}}$

d) $f = \frac{\omega}{2\pi}$

$\omega = \sqrt{\frac{+e^2}{4\pi m\varepsilon_0 R^3}}$

$\boxed{f = \frac{1}{2\pi}\sqrt{\frac{+e^2}{4\pi m\varepsilon_0 R^3}}}$

e) $4.54\times10^{14}\,Hz = f$

$4.54\times10^{14}\,Hz = \sqrt{\frac{(1.6\times10^{-19}C)^2}{4\pi(m_e)\varepsilon_0 R^3}}\left(\frac{1}{2\pi}\right)$

$8.14\times10^{30} = \frac{(1.6\times10^{-19}C)^2}{4\pi(m_e\varepsilon_0)R^3}$

$R^3 = 3.1\times10^{-29}\,m^3$

$\boxed{R = 3.14\times10^{-10}\,m}$

f) $\boxed{\text{correct magnitude}}$

g) if $r > R$: $E(r) = \frac{Q}{4\pi\varepsilon_0 r^2}$

$F = \frac{-e^2}{4\pi\varepsilon_0 r^2}$

$\boxed{\text{Yes, not SHM, F is not } \propto r}$

22.62) a) $Q = Q_1 + Q_2$

$Q_1 = \int_0^{R/2} \rho 4\pi r^2 \partial r$

$Q_1 = \int_0^{R/2}(\frac{3\alpha r}{2R})4\pi r^2 \partial r$

$Q_1 = \frac{12\pi\alpha}{2R}\int_0^{R/2} r^3\partial r$

$= \frac{6\pi\alpha}{2R}\left[\frac{r^4}{4}\right]_0^{R/2}$

$= \frac{6\pi\alpha}{2R}\left(\frac{R^4}{64}\right) = \frac{6\pi\alpha R^{4\,3}}{128 R}$

$Q_2 = \int_{R/2}^{R}\alpha(1 - (\frac{r}{R})^2)4\pi r^2 \partial r$

$4\pi\alpha\int_{R/2}^{R} r^2 - (\frac{r^4}{R^2})\partial r$

$4\pi\alpha\left[(\frac{r^3}{3})_{R/2}^{R} - \frac{1}{R^2}(\frac{r^5}{5})_{R/2}^{R}\right]$

$\downarrow \qquad \downarrow$

$\frac{R^3}{3} - \frac{R^3}{24} \quad - \frac{R^5}{5} + \frac{R^5}{160}$

$4\pi R^3\alpha(\frac{1}{3} - \frac{1}{24} - \frac{1}{5} + \frac{1}{160})$

$\pi R^3\alpha(\frac{4}{3} - \frac{1}{6} - \frac{4}{5} + \frac{1}{40})$

$= \pi R^3\alpha(\frac{47}{120})$

$Q = \frac{6\pi R^3\alpha}{128} + \frac{47\pi R^3\alpha}{120}$

$\boxed{\alpha = \frac{480Q}{233\pi R^3}}$

b) $\Phi = EA = \frac{q_{encl}}{\varepsilon_0}$

$4\pi r^2 E = \frac{q_{encl}}{\varepsilon_0}$

$q_{encl} = \rho V$

$\int_0^r \rho 4\pi r^2$

$= \int_0^r \left(\frac{3\alpha r}{2R}\right) 4\pi r^2 dr$

$\frac{6\pi\alpha}{R} \int_0^r r^3 dr$

$\frac{6\pi\alpha}{R}\left(\frac{r^4}{4}\right)$

$\frac{6\pi r^4}{4R}\left(\frac{480Q}{233\pi R^3}\right)$

$\frac{720Qr^4}{233R^4}$

$\boxed{E = \frac{180Qr^2}{233\pi\varepsilon R^4}}$

c) $\int_{R/2}^r \alpha\left(1 - \frac{r^2}{R^2}\right) 4\pi r^2 dr$

$4\pi\alpha \int_{R/2}^r \left(r^2 - \frac{r^4}{R^2}\right) dr$

$4\pi\alpha\left[\left(\frac{r^3}{3} - \frac{r^5}{5R^2}\right) - \left(\frac{R^3}{24} - \frac{R^5}{160R^2}\right)\right]$

$= \left(\frac{1920Q}{233}\right)\left[\left(\frac{r^3}{3R^3} - \frac{r^5}{5R^5}\right) - \frac{23}{1920}\right]$

$\boxed{E(r) = \frac{1}{4\pi r^2 \varepsilon_0} \cdot \text{—}\text{''}}$

d) $EA = \frac{q_{encl}}{\varepsilon_0}$

$\boxed{E = \frac{Q}{\varepsilon_0 A} = \frac{Q}{\varepsilon_0 4\pi r^2}}$

e) $q_{encl} = \frac{47}{120}\pi R^3 \alpha$

$\frac{47 \cancel{\pi R^3 \alpha}}{120}$

$\frac{47\cancel{\pi R^3 \alpha}}{120} + \frac{3 \cancel{Q\pi R^3}}{\cancel{480}\ 32}$

$\frac{\frac{47}{120}}{\frac{47}{120} + \frac{3}{32}}$

$= \boxed{0.807}$

f) $E\left(\frac{R}{2}\right) = \frac{1}{4\pi\left(\frac{R}{2}\right)^2 \varepsilon_0}\left(\frac{1920Q}{233}\right)\left(\left(\frac{\left(\frac{R}{2}\right)^3}{3} - \frac{\left(\frac{R}{2}\right)^5}{5}\right) - \frac{23}{1920}\right)$

$E\left(\frac{R}{2}\right) = \frac{1}{\pi R^2 \varepsilon_0}\left(\frac{1920Q}{233}\right)\left(\frac{R^3}{24} - \frac{R^5}{160} - \frac{23}{1920}\right) X$

$E\left(\frac{R}{2}\right) = \frac{180Q\left(\frac{R}{2}\right)^2}{233\pi\varepsilon_0 R^4}$

$E\left(\frac{R}{2}\right) = \frac{180Q(R^2)\left(\frac{1}{4}\right)}{233\pi\varepsilon_0 R^4}$

$\boxed{E\left(\frac{R}{2}\right) = \frac{45Q}{233\pi R^2 \varepsilon_0}}$

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