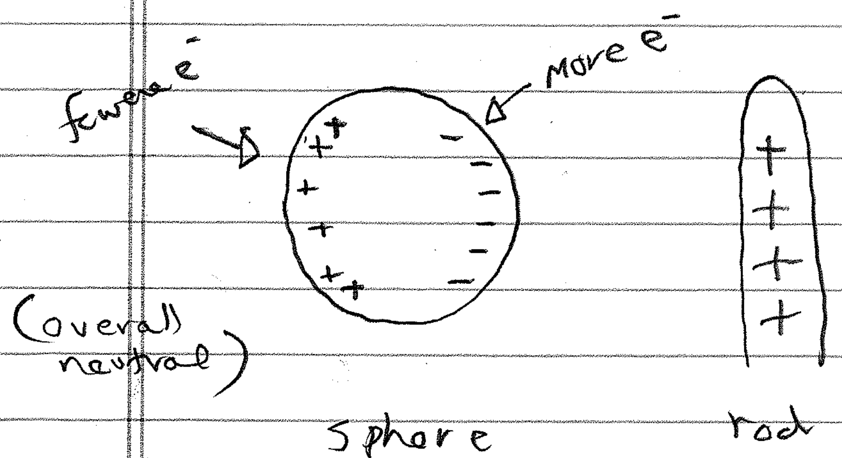
1.

Physics 9C HW 1 Winter 2016

21: Q5, Q8, Q23; 12, 22, 27, 30, 47, 49
61, 64, 76, 90, 93, 96, 104a-c

Q5 The metal sphere is initially uncharged but, because it is a metal, the electrons can redistribute themselves. They are attracted to the positive rod



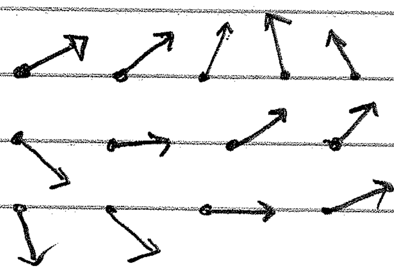
Since region with more e^- is closer, the net force is attractive.

After rod touches ball some of its + charge flows onto ball. Now ball and rod are both + charged and they repel

Q8 Moving e^- carry current in a solid. (The + charged nucleii are fixed in position.) But a moving e^- also has kinetic energy, so it can transport heat (remember temperature is a measure of velocity of particles) as well,

2.

$\boxed{Q23}$ A vector field assigns a vector (an arrow) to every point in space. A scalar field assigns a number to every point in space. Temperature is a single number so it forms a scalar field. Velocity is a vector so it forms a vector field.



28°	42°	56°
13°	20°	35°
3°	17°	22°

Velocity of air:
A vector at each point in space

temperature of air:
A number at each point in space

$\boxed{12}$

$$\frac{1 \text{ gram}}{1.67 \cdot 10^{-24} \text{ gram/proton}} = 6 \cdot 10^{23} \text{ protons}$$

Do you recognize Avagadro's #?

$$F = 9 \cdot 10^9 \frac{\left[(6 \cdot 10^{23})(1.6 \cdot 10^{-19})\right]^2}{3.84 \cdot 10^8}$$

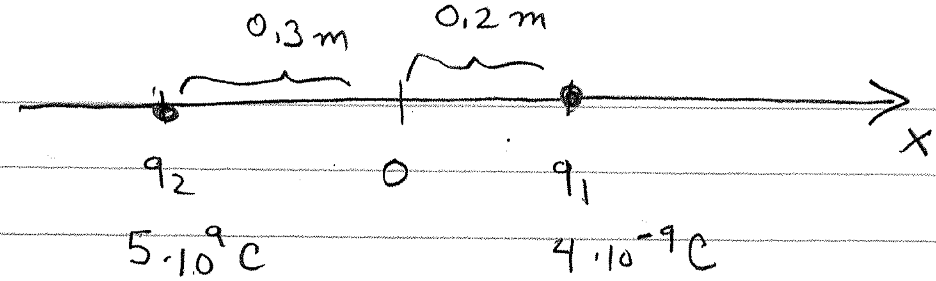
each proton has charge $1.6 \cdot 10^{-19}$ Coulomb

distance between earth and moon, in meters

$$= 2.2 \cdot 10^9 \text{ Newtons}$$

3.

$\boxed{22}$

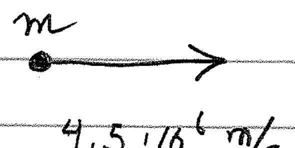


$$|\vec{F}_1| = (9\cdot10^9)\frac{(4\cdot10^{-9})(6\cdot10^{-9})}{(.2)^2} = 5.4\cdot10^{-6}\,N \quad \text{in } +\hat{x} \text{ dir}$$

$$|\vec{F}_2| = (9\cdot10^9)\frac{(5\cdot10^{-9})(6\cdot10^{-9})}{(.3)^2} = 3\cdot10^{-6}\,N \quad \text{in } -\hat{x} \text{ dir}$$

$$F_{TOT} = 2.4\cdot10^{-6}\,N \text{ in } +\hat{x} \text{ dir}$$

$\boxed{27}$



a) Need $\vec{E}$ field in $-\hat{x}$ direction and must give acceleration

$$v^2 - v_0^2 = 2a(x - x_0)$$

$$0 - (4.5\cdot10^6)^2 = 2a(.032)$$

$$a = -3.16\cdot10^{14}\ m/s^2$$

$$a = F/m = Eq/m = E\,\frac{1.6\cdot10^{-19}}{1.67\cdot10^{-27}}$$

$$E = 3.16\cdot10^{14}\,\frac{1.67\cdot10^{-27}}{1.6\cdot10^{-19}} = 3.3\cdot10^{6}\ N/C$$

4.

27 cont'd

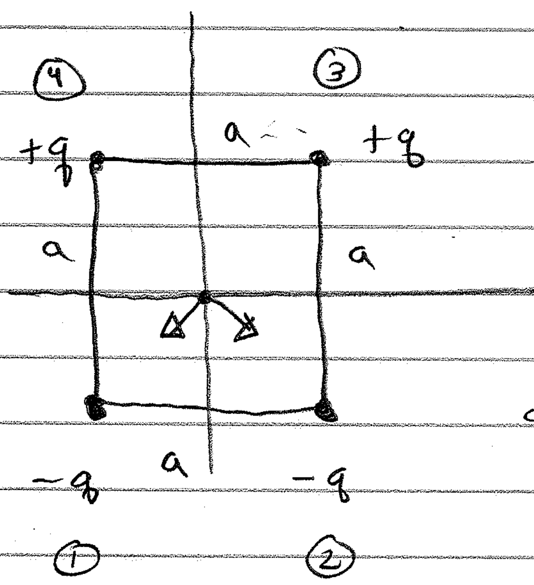
b) $v - v_0 = at$

$0 - 4.5 \cdot 10^{6} = (-3.16 \cdot 10^{+14})\, t \qquad t = 1.42 \cdot 10^{-8}$ sec

c) $m = 9.11 \cdot 10^{-31} \qquad q = \text{same} = 1.6 \cdot 10^{-19}$

$E = 1.8 \cdot 10^{3}$ N/C

$\boxed{30}$



$|\vec{E}| = kq/(\sqrt{2}a)^2 = kq/2a^2$

for all 4 charges

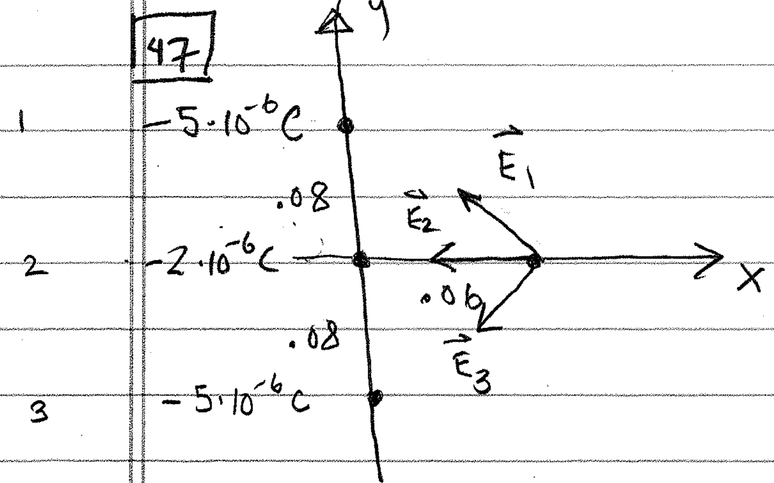
charge #	E_x	E_y
1	$-\frac{kQ}{2a^2}\frac{\sqrt{2}}{2}$	$-\frac{kQ}{2a^2}\frac{\sqrt{2}}{2}$
2	$+\frac{kQ}{2a^2}\frac{\sqrt{2}}{2}$	$-\frac{kQ}{2a^2}\frac{\sqrt{2}}{2}$
3	$-\frac{kQ}{2a^2}\frac{\sqrt{2}}{2}$	$-\frac{kQ}{2a^2}\frac{\sqrt{2}}{2}$
4	$+\frac{kQ}{2a^2}\frac{\sqrt{2}}{2}$	$-\frac{kQ}{2a^2}\frac{\sqrt{2}}{2}$

$E_x^{tot} = 0$

$E_y^{tot} = -\frac{kQ\sqrt{2}}{a^2}$

5.

$\boxed{47}$



	E_x	E_y
①	$-4.5\cdot10^{6}(.6)$	$4.5\cdot10^{6}(.8)$
②	$-5\cdot10^{6}$	0
③	$-4.5\cdot10^{6}(.6)$	$-4.5\cdot10^{6}(.8)$
TOT	$-9.4\cdot10^{6}\ \frac{N}{C}$	0

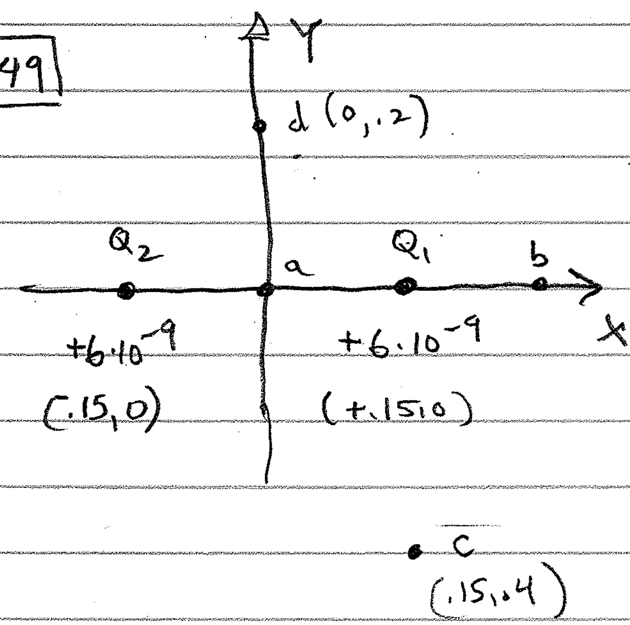
$$|\vec{E}| = kQ/r^2$$

$$|\vec{E}_3| = |\vec{E}_1| = \frac{9\cdot10^{9}(5\cdot10^{-6})}{(.06)^2+(.08)^2} = 4.5\cdot10^{6}\ \frac{N}{C}$$

$$\vec{E} = -9.4\cdot10^{6}\,\hat{\imath}\ \frac{N}{C}$$

$$|\vec{E}_2| = \frac{9\cdot10^{9}(2\cdot10^{-6})}{(.06)^2} = 5\cdot10^{6}\ \frac{N}{C}$$

$\boxed{49}$



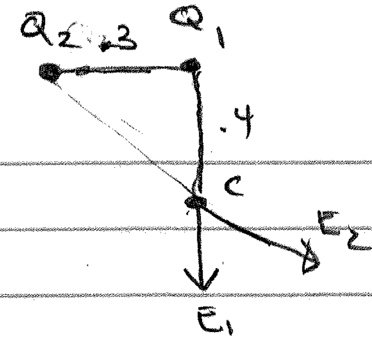
a) $\vec{E} = 0$ at origin because $\vec{E}_1 = -\vec{E}_2$

b) $\vec{E}_1 = \dfrac{(9\cdot10^{9})(6\cdot10^{-9})}{(.15)^2}\hat{x}$

$\vec{E}_2 = \dfrac{(9\cdot10^{9})(6\cdot10^{-9})}{(.45)^2}\hat{x}$

$\vec{E}_1 + \vec{E}_2 = (2400 + 267)\hat{x} = 2667\hat{x}$ N/C

6.



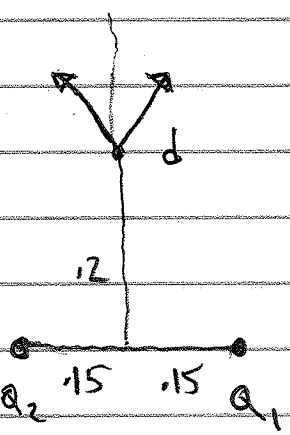
49 cont'd

c) $\vec{E}_1 = \dfrac{-(9\cdot 10^9)(6\cdot 10^{-9})}{(.4)^2}\,\hat{y} = -338\,\hat{y}\ \text{N/c}$

$$\vec{E}_2 = \frac{(9\cdot 10^9)(6\cdot 10^{-9})}{\underbrace{(.3)^2+(.4)^2}_{(.5)^2}}\left\{\frac{.3}{.5}\hat{x} - \frac{.4}{.5}\hat{y}\right)$$

$= 130\,\hat{x} - 173\,\hat{y}\ \text{N/c}$ $\quad\vec{E}_1 + \vec{E}_2 = (130\,\hat{x} - 411\,\hat{y})\,\frac{N}{c}$

d)



$\vec{E}_1 + \vec{E}_2$ will be in $\hat{y}$ direction

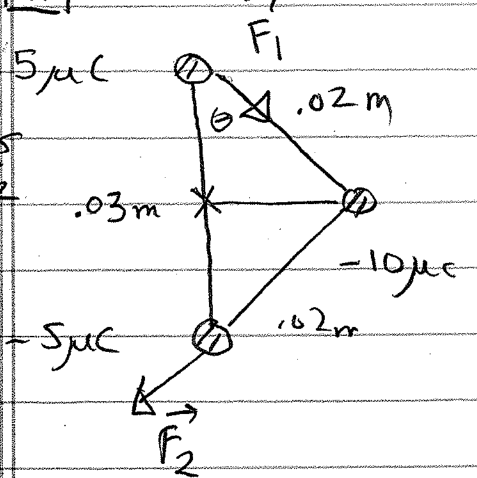
$$2\;\frac{9\cdot 10^9\,(6\cdot 10^{-9})}{(.15)^2+(.2)^2}\;\frac{.2}{\sqrt{(.15)^2+(.2)^2}}$$

2 contribution $\quad |E_1| = |E_2| \quad$ y component

$= 1382\,\hat{y}\ \text{N/c}$

7.

$\boxed{61}$



$\theta = \cos^{-1}\frac{.015}{.02}$

$= 41^\circ$

a) $\vec{F}_1 + \vec{F}_2$ will be in $\hat{y}$ direction

$$\underbrace{\frac{(9 \cdot 10^9)(5 \cdot 10^{-6})(10 \cdot 10^{-6})}{(.02)^2}}_{|\vec{F}_1| = |\vec{F}_2|} \quad 2 \quad \frac{.015}{.02}$$

2 contributions

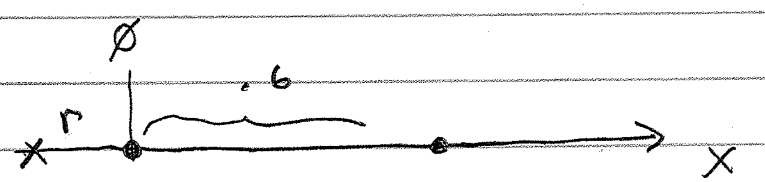
Y comp

$$\vec{F}_{TOT} = -1688\,\hat{y}\ N$$

b) $\tau =$ clockwise, 2 equal contributions $F r \sin\theta$

$$\tau = -2\ \underset{F}{(1688)}\ \underset{r}{(.015)}\ \underset{\sin\theta}{(.66)} = 33.4\ N\text{-}m$$

$\boxed{64}$



$Q_1 = +2.5\mu C \quad Q_2 = -3.5\mu C$

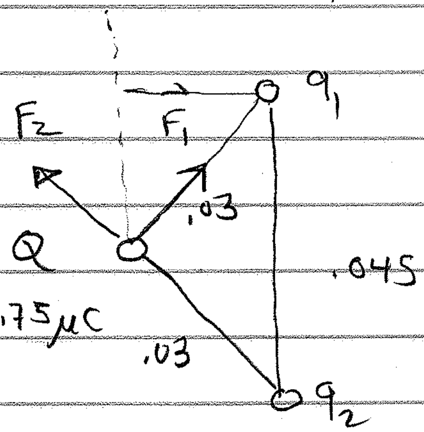
must be to left of 2.5 μC charge because in between charges F_1 & F_2 in same direction and to right of −3.5 μC charge $F_2 > F_1$ (bigger Q_2 and smaller r!)

$$q\ 9 \cdot 10^9 \left\{ -\frac{2.5\mu C}{r^2} + \frac{3.5\mu C}{(r+.6)^2} \right\} = 0 \qquad \frac{2.5}{r^2} = \frac{3.5}{(r+.6)^2}$$

64 cont'd
$$\frac{(r+.6)^2}{3.5} = \frac{r^2}{2.5} \qquad \frac{r+.6}{1.87} = \frac{r}{1.58}$$

$$r = 3.27 \text{ m}$$

$\boxed{76}$



If $\vec{a}$ is straight up we must have q_1 and q_2 of same size, with $q_1 > 0$ and $q_2 < 0$. See picture for forces that make $\vec{a}$ upwards

$F = ma$
$$2 \quad 9 \cdot 10^9 \left\{ \frac{q_1}{(.03)^2} \quad \frac{.0225}{.03} \right\} 1.75 \cdot 10^{-6}$$

2 contributions

y component

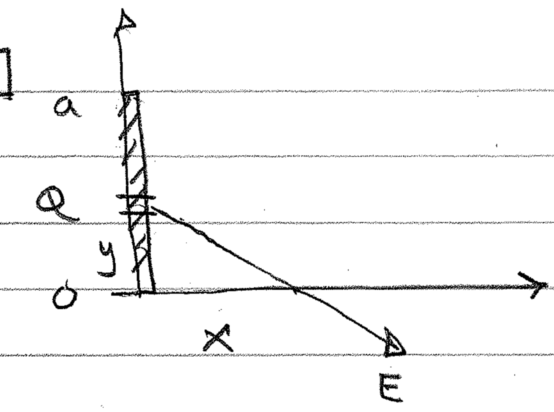
$$= .005 \quad 324$$

m a

$q_1 = 62$ nC

$q_2 = -q_1$

$\boxed{90}$



$$E_x = \int_0^a \frac{\overbrace{Q\,dy/a}^{dq}\; k}{x^2+y^2}\,\frac{x}{\sqrt{x^2+y^2}}$$

$$y = x\tan\theta$$

$$= \frac{kQx}{a}\int \frac{x\sec^2\theta\,d\theta}{x^3\sec^3\theta}$$

$$= \frac{kQ}{ax}\sin\theta\Big|$$

$$\frac{y}{\sqrt{x^2+y^2}}\Big|_0^a$$

$$E_x = \frac{kQ}{ax}\left\{\frac{a}{\sqrt{x^2+a^2}} - 0\right\} = \frac{kQ}{x\sqrt{x^2+a^2}}$$

Consider limit $x >> a$ $\quad x^2+a^2 \approx x^2$

$E_x = kQ/x^2$ as expected

$$E_y = -\int_0^a \frac{Q\,dy/a\; k}{x^2+y^2}\,\frac{y}{\sqrt{x^2+y^2}}$$

$$= -\frac{kQ}{a}\int \frac{x\tan\theta\; x\sec^2\theta\,d\theta}{x^3\sec^3\theta} = -\frac{kQ}{ax}\,\left(-\cos\theta\right)\Big|$$

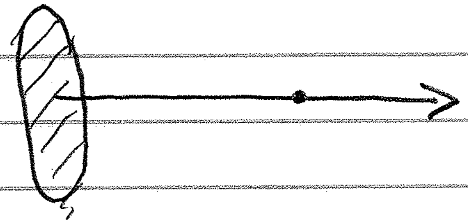
$$= \frac{kQ}{ax}\,\frac{x}{\sqrt{x^2+y^2}}\Big|_0^a = \frac{kQ}{a}\left\{\frac{1}{\sqrt{x^2+a^2}} - \frac{1}{x}\right\}$$

limit $x >> a$ $\quad (x^2+a^2)^{-1/2} \approx \left[x^2(1+a^2/x^2)\right]^{-1/2} = \frac{1}{x}\left(1-\frac{a^2}{2x^2}\right)$

$$E_y = \frac{kQ}{a}\left\{\frac{1}{x} - \frac{a^2}{2x^3} - \frac{1}{x}\right\} = -\frac{kQ}{x^2}\,\frac{a}{2x} \quad \text{as expected}$$

tan of angle to center

10. $\boxed{93}$



$$E = \frac{\sigma}{2\epsilon_0}\left\{1 - \frac{1}{\sqrt{\frac{R^2}{x^2}+1}}\right\}$$

$R = .025$

$Q = 7 \cdot 10^{-12}$

$$= \underbrace{\frac{(7 \cdot 10^{-12})}{\pi(.025)^2}}_{\sigma}\ \frac{1}{2(8.85 \cdot 10^{-12})}\left\{1 - \frac{1}{\sqrt{\left(\frac{.025}{.2}\right)^2+1}}\right.$$

$E = 1,555\ N/C$

b) $R/x \ll 1 \quad = \left(1 + R^2/x^2\right)^{-1/2} \approx 1 - R^2/2x^2$

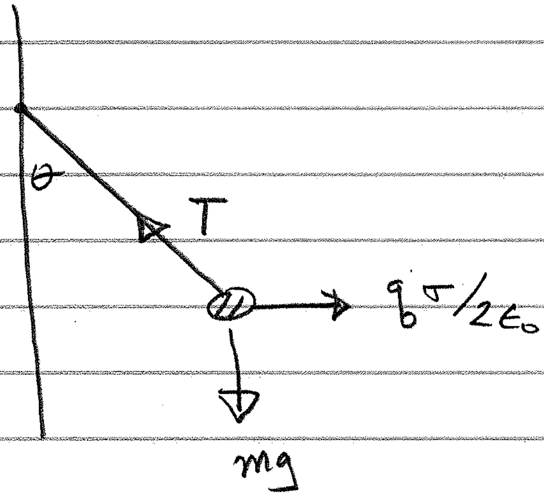
$$E = \frac{\sigma}{2\epsilon_0}\left\{\frac{R^2}{2x^2}\right\} = \frac{\sigma \pi R^2}{4\pi\epsilon_0 x^2} = kQ/x^2 = \frac{Q}{4\pi\epsilon_0 x^2}$$

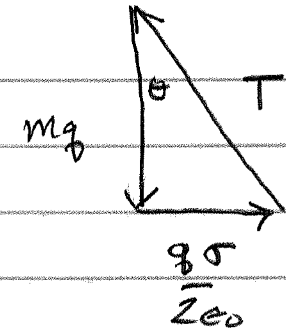
c) Should be a bit smaller because portions of disk are a bit further than .20 m away (the point charge distance)

$$kQ/x^2 = 9 \cdot 10^9 (7 \cdot 10^{-12})/(.2)^2 = 1.575\ N/C$$

d) % difference @ 20 cm is $\frac{.02}{1.575}\ 100 = 1.3\%$

$\boxed{96}$





$\tan\theta = q\sigma / 2mg\epsilon_0$

$\boxed{104}$ a) $Q = \sigma\pi(R_2^2 - R_1^2)$

b) Use formula 21.11 from text, subtracting missing piece

$$E = \frac{\sigma}{2\epsilon_0}\left\{1 - \frac{1}{\sqrt{R_2^2/x^2+1}} - \left(1 - \frac{1}{\sqrt{R_1^2/x^2+1}}\right)\right\}$$

$$= \frac{\sigma}{2\epsilon_0}\left\{\frac{1}{\sqrt{R_1^2/x^2+1}} - \frac{1}{\sqrt{R_2^2/x^2+1}}\right\}$$

c) If $x \ll R_1, R_2$ $\quad E \simeq \frac{\sigma}{2\epsilon_0}\left\{\frac{1}{R_1/x} - 1/_{R_2/x}\right\}$

$$= \frac{\sigma}{2\epsilon_0}\left(\frac{1}{R_1} - \frac{1}{R_2}\right)x$$

d) Since $E \sim x$ $\quad F = qE \sim x$ also so this is a spring-like force (Hookes law).

12

104 cont'd

spring constant

$$w^2 = \frac{K}{m} = \frac{\sigma}{2\epsilon_0 m}\left(\frac{1}{R_1} - \frac{1}{R_2}\right) q_1$$