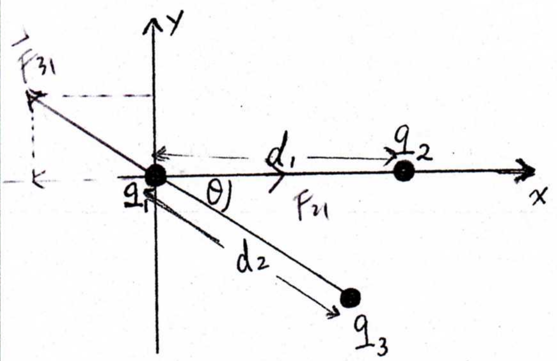
Physics 2B Exam I **Name:** Solution
Winter **Lab:** ____________________

1. (25 points) Three point charges are fixed at the locations (see the figure):
q_1 at the origin with positive charge q, q_2 and q_3 with unknown charge.
The net electric force on q_1 has a magnitude F and is directed in the +y direction.
(a) What is the sign of the charge q_3 .
(b) What is the sign of the charge q_2 .
(c) Suppose that the magnitude of q_3 is determined to be 2q, calculate q_2 in terms of q, d_1 , d_2 and θ.



$q_1 q_3$ repulsion.

q_1 ⊕. q_3 ⊕ (5) Sign

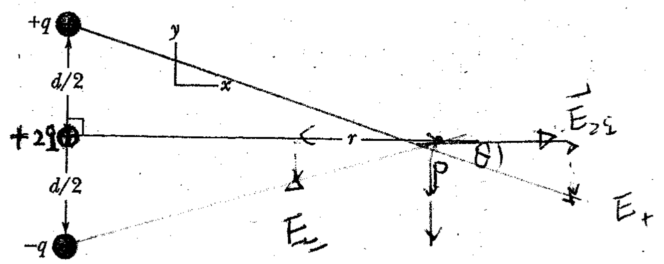
$q_1 q_2$ attraction q_2 ⊖ (5)

equation

$$F_{21} = k\frac{q_2 q_1}{d_1^2} = F_{31x} = k\cdot\frac{q_1 q_3}{d_2^2}\cos\theta \quad (10)$$

$$q_2 = \left(\frac{d_1}{d_2}\right)^2 \cdot 2q \cdot \cos\theta \quad (5)$$ answer

2. (25 points) An electric dipole with charge +q and −q and a separation d. We put +2q at the midpoint on the dipole axis. What are the magnitude and direction of the electric field at point P located at distance r from the midpoint?



$E_+ = E_-$

cancel

$E_{+x} + E_{-x} = 0$ ✓ (5)

$\vec{E}_P = E_x\hat{i} + E_y\hat{j}$

$E_y = 2E_{+y} = 2E_+\sin\alpha$ (5)

$= 2 \cdot \dfrac{q}{4\pi\varepsilon_0\left[r^2 + \left(\frac{d}{2}\right)^2\right]} \quad \dfrac{\frac{d}{2}}{\sqrt{\left(r^2 + \left(\frac{d}{2}\right)^2\right)}}$ ✓ ✓ $\sin\alpha$ (5)

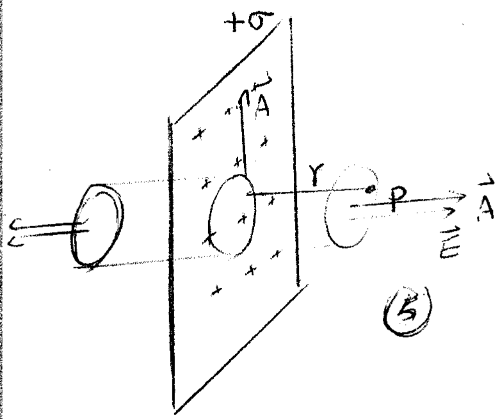
$= \dfrac{qd}{4\pi\varepsilon_0\left(r^2 + \left(\frac{d}{2}\right)^2\right]^{3/2}}$

$E_x = E_{2q} = \dfrac{2q}{4\pi\varepsilon_0 r^2}$

$\vec{E} = \dfrac{2q}{4\pi\varepsilon_0 r^2}(\hat{i})$ ✓ $- \dfrac{qd}{4\pi\varepsilon_0\left(r^2 + \left(\frac{d}{2}\right)^2\right]^{3/2}}(\hat{j})$ ✓

(10)

3. (25 points) A thin, infinite nonconducting sheet with uniform positive surface charge density $+\sigma$. (a) Find the electric field a distance r in front of the sheet by using Gauss' law. (b) If there are two large parallel nonconducting sheets with uniform charge density $+\sigma$ and $-\sigma$, calculate the electric field at point P.



choose a cylinder

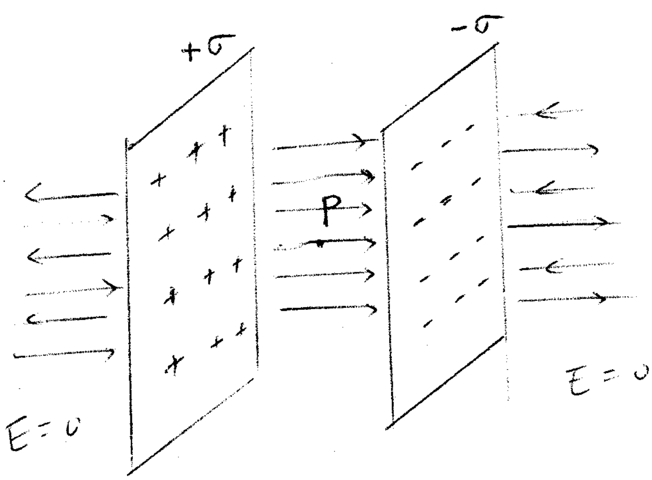
gauss' Law

$$\Phi = \Phi_L + \Phi_R + \Phi_S \quad (5)$$

$$= E\cdot A\cdot\cos 0^\circ + E\cdot A\cdot\cos 0^\circ + E\cdot A\cdot\cancel{\cos 90^\circ}$$

$$= 2EA = \frac{q_{in}}{\varepsilon_0} = \frac{\sigma A}{\varepsilon_0}$$

$$E_P = \frac{\sigma}{2\varepsilon_0} \quad (5)$$



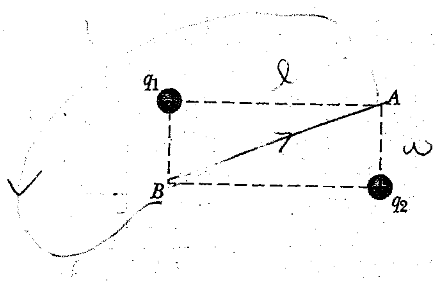
$$E_P = E + E = 2E$$

$$= 2\cdot\frac{\sigma}{2\varepsilon_0}$$

$$= \frac{\sigma}{\varepsilon_0} \quad (5)$$

direction (5)

4. (25 points) A rectangle of length l = 15cm and width ω = 5cm, q_1= -5μC, q_2=+2μC With V=0 at infinite, (a) what are the electric potentials Va at point A and Vb at point B? (b) How much work is required to move a charge q_3=+3μC from B to A along a diagonal of the rectangle? (c) How much work is required to move q_3 along any curved path from A to B? (k = $1/4\pi\varepsilon_0$ = 9*10 ^9 N m²/C²)



$$V_A = \frac{q_1}{4\pi\varepsilon_0 l} + \frac{q_2}{4\pi\varepsilon_0 \omega}$$

$$= \frac{1}{4\pi\varepsilon_0}\left(\frac{-5\times10^{-6}}{0.15} + \frac{2\times10^{-6}}{0.05}\right)$$

$$= 6\times10^{4}\ V \quad (8)$$

$$V_B = \frac{q_1}{4\pi\varepsilon_0 \omega} + \frac{q_2}{4\pi\varepsilon_0 l}$$

$$= \frac{1}{4\pi\varepsilon_0}\left(\frac{-5\times10^{-6}}{0.05} + \frac{2\times10^{-6}}{0.15}\right)$$

$$= -7.8\times10^{5}\ V \quad (7)$$

$$\underset{B\to A}{W_{app}} = q_3 \Delta V = q_3(V_A - V_B) = 2.52\ J \quad (5)$$

$$\underset{A\to B}{W_{app}} = q_3 \cdot \Delta V = q_3(V_B - V_A) = -2.52\ J \quad (5)$$