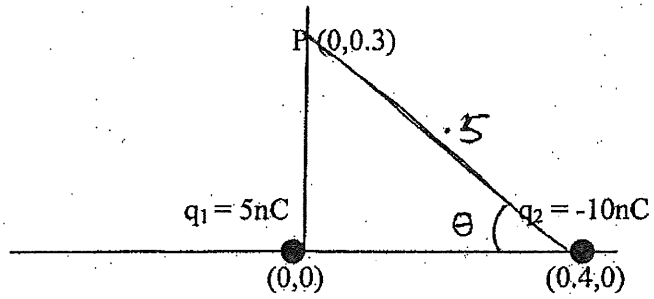
40 points

1. Charge $q_1 = 5nC$ is at the origin and charge $q_2 = -10nC$ is at the point (0.4,0), where all coordinates are in meters (see sketch below). Point P has coordinates (0,0.3). ($1nC = 10^{-9}C$).



(a) Calculate the components (E_{1x},E_{1y}) of the electric field at P due to the charge q_1.

$$E_1 = \frac{(9\cdot10^9)(5\cdot10^{-9})}{(.3)^2} = 500\ \frac{N}{C} \text{ upwards}$$

$E_{1x} = 0$

$E_{1y} = 500\ N/C$

(b) Calculate the components (E_{2x},E_{2y}) of the electric field at P due to the charge q_2.

$$E_2 = \frac{(9\cdot10^9)(10\cdot10^{-9})}{(.4)^2+(.3)^2} = 360\ \frac{N}{C}$$

θ, E_2

$E_{2x} = E_2\cos\theta = E_2\cdot\frac{4}{5} = 288\ N/C$

$E_{2y} = -E_2\sin\theta = -E_2\cdot\frac{3}{5} = -216\ N/C$

$E_{2x} = 288\ N/C$

$E_{2y} = -216\ N/C$

(c) Calculate the components (E_x,E_y) of the total electric field at P due to the two charges.

$E_x = E_{1x} + E_{2x} = 288\ N/C$

$E_y = E_{1y} + E_{2y} = 284\ N/C$

$E_x = 288\ N/C$

$E_y = 284\ N/C$

(d) A charge $q_3 = -10nC$ is placed at P. Calculate the magnitude and direction of the force experienced by it. Express the direction as a counterclockwise angle measured from the positive x-axis.

$$\vec{F} = q_3\vec{E} = (-10\cdot10^{-9})(288\hat{i} + 284\hat{j})\ N$$

288, 284, θ

$$|F| = 10^{-8}\sqrt{288^2+284^2} = 4.04\times10^{-6}\ N$$

$$\theta = \tan^{-1}\left(\frac{284}{288}\right) = 44.6°$$

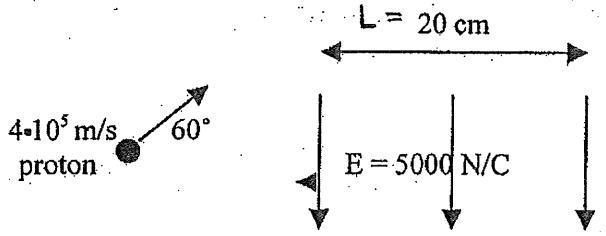
Direction $= 180 + \theta = 224.6°$ 2

Mag. $= 4.04\times10^{-6}\ N$

Dirn. $= 224.6°$

40 points

2. A proton is fired with a velocity of $4 \cdot 10^5$ m/s at an angle of 60° above the horizontal into a region containing a uniform electric field of 5000 N/C pointing vertically downwards, as shown below. The field region extends for a horizontal distance of 20cm. Choose a Cartesian coordinate system with its origin at the initial position of the proton, x-axis pointing to the right and y-axis pointing up, and ignore the effect of gravity in doing this problem.



(a) Calculate the acceleration of the proton in the field.

$$a = \frac{qE}{m} = \frac{(1.6\times10^{-19})(5000)}{1.672\times10^{-27}}$$

$$= 4.78\times10^{11}\ m/s^2 \text{ downwards}$$

$a_x = 0$
$a_y = -4.78\times10^{11}\ m/s^2$

(b) Calculate the time spent by the proton in the field.

$$V_x = V\cos60^\circ = (4\cdot10^5)\cos60^\circ = 2\cdot10^5$$

$$\text{time} = \frac{L}{V_x} = \frac{.2}{2\cdot10^5} = 10^{-6}\ s$$

Time = 10^{-6} s

(c) Calculate the x- and y-components of velocity of the proton when it exits the field.

$V_x = 2\cdot10^5$ m/s → same as initial.

$$V_y = V_{y0} + a_y t = (4\cdot10^5)(\sin60^\circ) + (-4.78\times10^{11})(10^{-6})$$

$$= -1.32\times10^5\ m/s$$

$v_x = 2\cdot10^5$ m/s
$v_y = -1.32\cdot10^5$ m/s

(d) Calculate the vertical displacement of the proton relative to its initial position when it exits the field, and state whether it is above or below the initial position.

$$y = V_{y0}t + \tfrac{1}{2}a_y t^2 = (4\cdot10^5)(\sin60^\circ)(10^6) + \tfrac{1}{2}(-4.78\times10^{11})(10^6)^2$$

$$= .107\text{m} = 10.7\text{cm}$$

Disp. = .107m
Above or below?

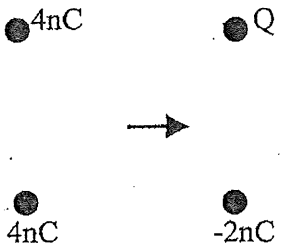
CORRECTED
4 PART A

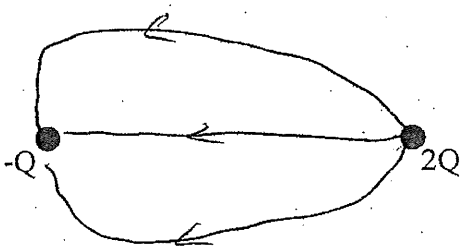
No calculations need be shown for any of the questions on this page.

10 points

3. (a) The left sketch below shows four point charges at the corners of a square. The electric field at the center of the square points horizontally to the right, as shown. Determine the magnitude and sign of the unknown charge Q. (5pts)

Q = −2nC





(b) The figure to the right above shows a positive charge 2Q and a negative charge –Q a certain distance apart. Draw at least three field lines passing through both charges, and also indicate the arrows on them. (5pts)

10 points

4. PART A. Three plastic balls A,B and C are found to have the following properties: A and B strongly attract each other, and B and C neither attract nor repel each other. Ignore any polarization of the balls. Circle all of the following statements that correctly describe the properties of A and C. (5pts)

(a) A is neutral and C is charged (b) A is charged and C is neutral
(c) A and C repel each other (d) A and C attract each other (e) A and C neither attract nor repel.

PART B. A metal sphere isolated from its surroundings has some negative charge put on it. Circle all of the following statements that are correct. (5pts)

(a) The electric field just outside the sphere vanishes
(b) The electric field just outside the sphere is perpendicular to its surface and points inwards towards the center of the sphere
(c) The electric field just outside the sphere is perpendicular to its surface and points outwards from the center of the sphere
(d) The charge distributes itself uniformly throughout the volume of the sphere
(e) The charge distributes itself uniformly over the surface of the sphere