BRAC UNIVERSITY

Principles of Physics-II (PHY-112)

Department of Mathematics and Natural Sciences

Assignment: 01 — **Section**: 30

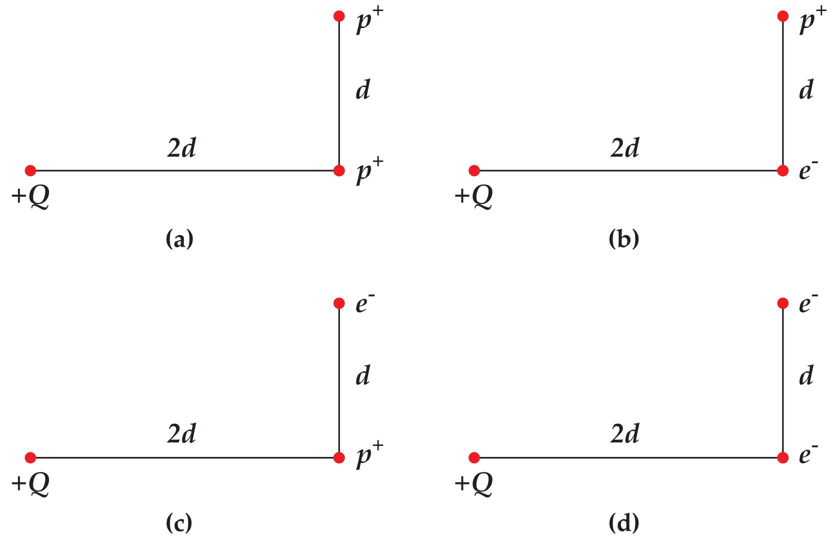
Dispatch Date: June 22, 2024

Submission Deadline: June 27, 2024

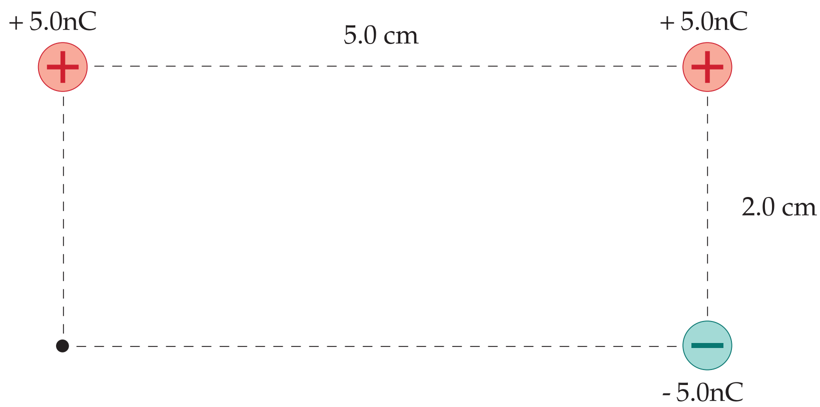
Duration: 6 Days **Summer 2024 (10F-31C)** Marks: 15

Attempt all questions. Show Your work in detail. Use SI units. 1:1 plagiarism will be strictly penalized.

1. The diagram shows four arrangements of charged particles. Rank the arrangements according to the magnitude of the net electrostatic force on the particle with charge $+Q$, greatest first. **Note**: $p^+ \equiv$ proton and $e^- \equiv$ electron. **Hint**: Measuring the angle once can be reused several times. **(5)**



2. The charge distribution setup shown below is a discrete one. The observation point is shown by the dot placed in one corner of this rectangle.



   (a) How would you convince someone that F_g on charged particles is safe to ignore in the realm of F_E? **Hint**: A small relevant calculation would help. **(3)**

   (b) What is the strength of the Electric field at the black dot location? Your answer should be a scalar. **(3)**

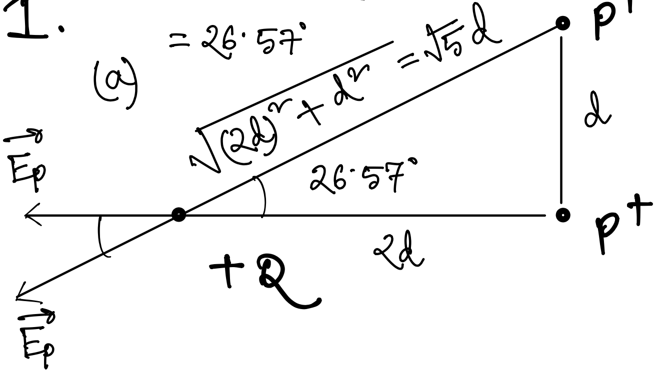
   (c) Find the direction of $\vec{E}$ at the dot. Give your answer in angle measured clockwise or counter-clockwise (specify which) from the positive x-axis. You can import values from (c). **(2)**

   (d) Now place an electron at the observation point from the rest. Will it move or stay still? If it moves, write the acceleration vector in component notation. **(2)**

S30 – Assignment #1

1. $\theta = \tan^{-1}\left(\frac{1}{2}\right)$
$= 26.57^\circ$

(a)



$d = 10^{-2}$ m.

$|q_p| = |q_e| = 1.602 \times 10^{-19}$ C.

$|Q| = 10^{-9}$ C.

$\vec{E_p} \rightarrow$ field due to proton

$\vec{E_e} \rightarrow$ field due to electron

$$\vec{E}_{net}^{(a)} = \vec{E_p} + \vec{E_p}$$

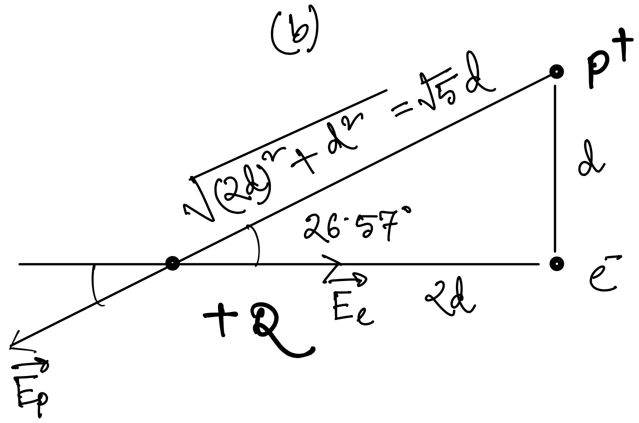
$$= \frac{C|q_p Q|}{(2d)^2}(-\hat{i}) + \frac{C|q_p Q|}{(\sqrt{5}d)^2}\cos(180^\circ + 26.57^\circ)\,\hat{i} + \frac{C|q_p Q|}{(\sqrt{5}d)^2}\sin(180^\circ + 26.57^\circ)\,\hat{j}$$

$$= (-3.59\,\hat{i} - 2.58\,\hat{i} - 1.29\,\hat{j}) \times 10^{-15}\ \text{NC}^{-1}.$$

$$= (-6.17\,\hat{i} - 1.29\,\hat{j}) \times 10^{-15}\ \text{NC}^{-1}.$$

$$|\vec{E}_{net}^{(a)}| = 6.274 \times 10^{-15}\ \text{NC}^{-1}.$$

(b)



(b) $\vec{E}_{net}^{(b)} = \vec{E_e} + \vec{E_p}$

$$= \frac{C|q_e Q|}{(2d)^2}(+\hat{i}) + \frac{C|q_p Q|}{(\sqrt{5}d)^2}\cos(180^\circ + 26.57^\circ)\,\hat{i}$$

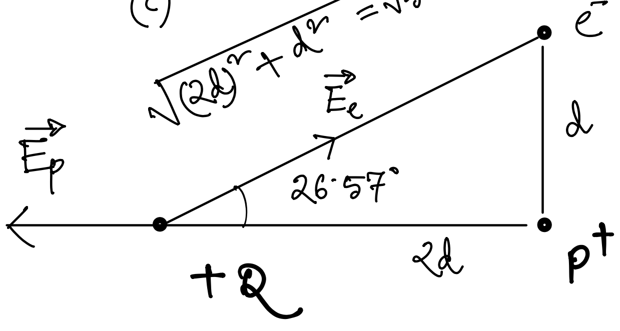
$$+ \frac{C|q_p Q|}{(\sqrt{5}d)^2}\sin(180^\circ + 26.57^\circ)\,\hat{j}$$

$$= (+3.59\,\hat{i} - 2.58\,\hat{i} - 1.29\,\hat{j}) \times 10^{-15}\ \text{NC}^{-1}.$$

$$= (+1.01\,\hat{i} - 1.29\,\hat{j}) \times 10^{-15}\ \text{NC}^{-1}.$$

$$|\vec{E}_{net}^{(b)}| = 1.644 \times 10^{-15}\ \text{NC}^{-1}.$$

(c)



(c) $\vec{E}_{net}^{(c)} = \vec{E_p} + \vec{E_e}$

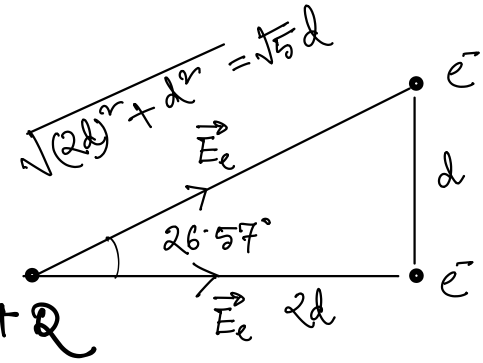
$$= \frac{C|q_p Q|}{(2d)^2}(-\hat{i}) + \frac{C|q_e Q|}{(\sqrt{5}d)^2}\cos(26.57^\circ)\,\hat{i} + \frac{C|q_e Q|}{(\sqrt{5}d)^2}\sin(26.57^\circ)\,\hat{j}$$

$$= \left(-3.59\hat{i} + 2.58\hat{i} + 1.29\hat{j}\right) \times 10^{-15}\ NC^{-1}.$$

$$= \left(-1.01\hat{i} + 1.29\hat{j}\right) \times 10^{-15}\ NC^{-1}.$$

$$\left|\vec{E}_{net}^{(c)}\right| = 1.644 \times 10^{-15}\ NC^{-1}.$$

(d)



(d) $\vec{E}_{net}^{(d)} = \vec{E}_e + \vec{E}_e$

$$= \frac{C|q_e Q|}{(2d)^2}(+\hat{i}) + \frac{C|q_e Q|}{(\sqrt{5}d)^2}\cos(26.57°)\,\hat{i} + \frac{C|q_e Q|}{(\sqrt{5}d)^2}\sin(26.57°)\,\hat{j}$$

$$= \left(+6.17\hat{i} + 1.29\hat{j}\right) \times 10^{-15}\ NC^{-1}.$$

$$\left|\vec{E}_{net}^{(d)}\right| = 6.274 \times 10^{-15}\ NC^{-1}.$$

Evidently, $\left|\vec{E}_{net}^{(a)}\right| = \left|\vec{E}_{net}^{(d)}\right|$, and $\left|\vec{E}_{net}^{(b)}\right| = \left|\vec{E}_{net}^{(c)}\right|$.

Ranking. $\left|\vec{E}_{net}^{(a)}\right| = \left|\vec{E}_{net}^{(d)}\right| > \left|\vec{E}_{net}^{(b)}\right| = \left|\vec{E}_{net}^{(c)}\right|$.

(2) (a) Imagine one proton and an electron are placed 1m apart from each other. You can try to find the gravitational and electrostatic attraction from between them to check their relative strength.

$$\frac{F_g}{F_E} = \frac{\frac{G m_p m_e}{r^2}}{\frac{C q_p q_e}{r^2}} = \frac{G m_p m_e}{C q_p q_e} \sim 10^{-40}.$$

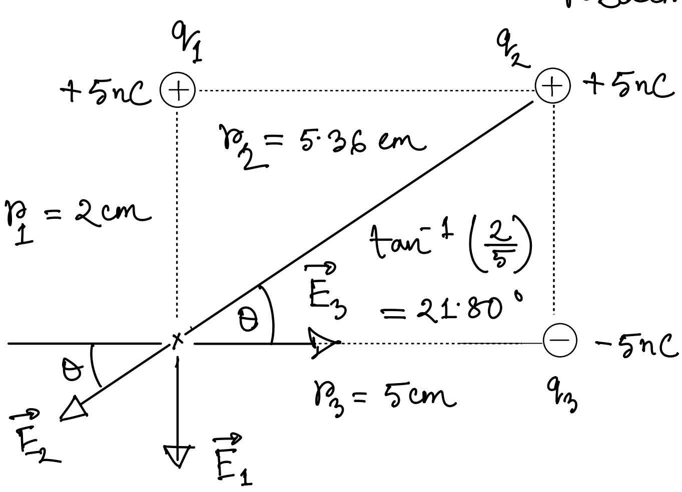
This shows that F_g is extremely weaker than F_E at electromagnetic realm.

(b)

$$E_1 = \left(\frac{C q_1}{r_1^2}\right) = 112344.3974\ NC^{-1}.$$

$$E_2 = \left(\frac{C q_2}{r_2^2}\right) = 15641.624\ NC^{-1}$$

$$E_3 = \left(\frac{C q_3}{r_3^2}\right) = 17975.10\ NC^{-1}.$$



$$\vec{E}_{net} = \vec{E}_1 + \vec{E}_2 + \vec{E}_3 .$$

$$= E_1(-\hat{j}) + E_2 \cos(180^\circ+\theta)\,\hat{i} + E_2 \sin(180^\circ+\theta)\,\hat{j} + E_3\hat{i}.$$

$$= (-112344.3974\,\hat{j} - 14523.0262\,\hat{i} - 5808.7960\,\hat{j} + 17975.10\,\hat{i})\ NC^{-1}.$$

$$= (+3452.074\,\hat{i} - 118153.193\,\hat{j})\ NC^{-1}.$$

$$|\vec{E}_{net}| = 118203.612\ NC^{-1}.$$

(c) $\vec{E}$-field direction:

(clockwise).

$$\tan^{-1}\left(\frac{E_y}{E_x}\right) = -88.33^\circ;\ \text{from the } +x\text{-axis}.$$

$$360^\circ - \tan^{-1}\left(\frac{E_y}{E_x}\right) \sim 271.67^\circ \text{ from the } +x\text{-axis}.$$

(Counterclockwise)

(d) Since there is a net field at the observation point, an incoming electron will feel an electric force that accele- -rate it.

☆ Negative charges accelerate opposite to $\vec{E}$'s direction

$$\vec{a}_e = \frac{q_e}{m_e}\vec{E}_{net}$$

$$= \frac{-1.602\times10^{-19}\,C}{9.1\times10^{-31}\,kg}(+3452.074\,\hat{i} - 118153.193\,\hat{j})\ NC^{-1}.$$

$$= (-6.077\times10^{14} + 2.080\times10^{16})\ ms^{-2}.$$