BYJU'S Home Learning Program

Topic covered:

- **Electrostatics (Session - 2) - JEE**

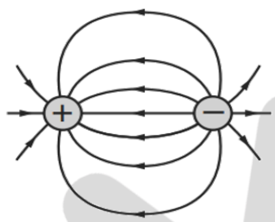
Worksheet

1. What is the value of the electric field 3 meters away from a point charge with a strength of $10\ \mu C$?

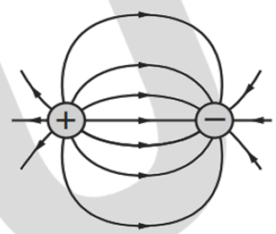
   a. $10000\ \frac{N}{C}$ b. $20000\ \frac{N}{C}$

   c. $30000\ \frac{N}{C}$ d. $40000\ \frac{N}{C}$

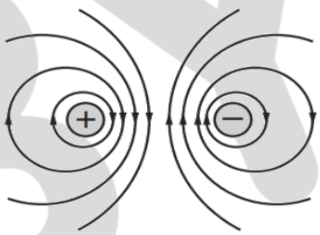
2. A positive charge and a negative charge of equal magnitude are placed a short distance apart. Which diagram best represents the associated electric field?

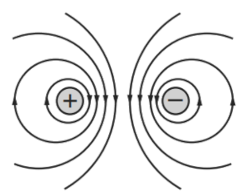
   a.

   b.

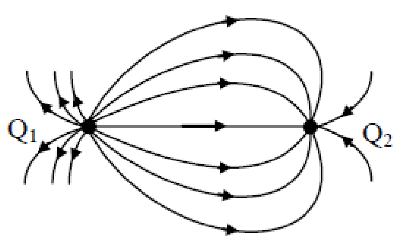
   

   c.

   d.

3. The electric field lines for a system of two charges Q_1 and Q_2 fixed at two different points on the x-axis are shown in the figure. Then $\frac{Q_1}{Q_2}$ might be

   a. $\frac{13}{9}$ b. $\frac{9}{13}$

   c. 1 d. Cannot be determined

4. Two charges $q_1$and q_2 are separated by a dielectric of dielectric constant 4 repel each other with a force of 10 N. Another charge q_3 is placed between $q_1$and q_2 such that the distance of q_3 from q_1 is 14 times the distance of q_3 from q_2. Now, the force of repulsion between q_1 and q_2 is (in N)
   a. 10
   b. 10 q_1
   c. $\frac{4q_2}{q_1}$
   d. $\frac{10q_1}{q_2}$

5. If two charges $+4e$ and $+e$ are at a distance x apart then at what distance charge q must be placed from $+e$, so that it is in equilibrium?
   a. $\frac{x}{2}$
   b. $\frac{x}{3}$
   c. $\frac{x}{6}$
   d. $\frac{2x}{3}$

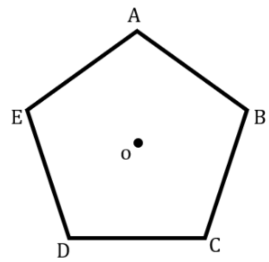
6. A certain charge Q is divided into two parts q and $Q-q$. How the charge Q and q must be related so that when q and $(Q-q)$ is placed at a certain distance apart experience maximum electrostatic repulsion
   a. $Q = 2q$
   b. $Q = 3q$
   c. $Q = 4q$
   d. $Q = 4q$

7. Determine the electric field vector at a distance of 0.50 m from a charge of -4 μC.
   a. $(-7.2 \times 10^4\ NC^{-1})\hat{r}$
   b. $(-14.4 \times 10^4\ NC^{-1})\hat{r}$
   c. $(-3.1 \times 10^4\ NC^{-1})\hat{r}$
   d. $(-6.2 \times 10^4\ NC^{-1})\hat{r}$

8. Imagine two point charges 2 m away from each other in vacuum. One of the charges has a strength of 3 μC. If the force between the charges is 0.0405 N, what is the strength of the second charge?
   a. 9 μC
   b. 6 μC
   c. 3 μC
   d. 12 μC

9. Two tiny spheres, each having mass m kg and charge q coulomb, are suspended from a point by insulating threads each l metre long but negligible mass. When the system is in equilibrium, each string makes an angle θ with the vertical.
   Choose the correct equation relating these quantities.
   a. q = $(2mg\ell^2 sin^2\theta tan\theta)4\pi\varepsilon_0$
   b. q = $(4mg\ell^2 sin^2\theta tan\theta)4\pi\varepsilon_0$
   c. $q^2 = (2mg\ell^2 sin^2\theta tan\theta)4\pi\varepsilon_0$
   d. $q^2 = (4mg\ell^2 sin^2\theta tan\theta)4\pi\varepsilon_0$

10. Four charges, each equal to q, are placed at the four vertices of a regular pentagon at B, C D and E respectively. The distance of each corner from the centre is a. Find the electric field at the centre of the pentagon.



a. $\frac{1}{4\pi\varepsilon_0}\frac{q}{a^2}$ along OB
b. $\frac{1}{4\pi\varepsilon_0}\frac{q}{a^2}$ along OA
c. $\frac{1}{4\pi\varepsilon_0}\frac{q}{a^2}$ along OE
d. $\frac{1}{4\pi\varepsilon_0}\frac{q}{a^2}$ along OE

11. Three charges, each equal to q, are placed at the three corners of a square of side a. Find the magnitude of electric field at the fourth corner.

a. $\frac{3}{4\sqrt{2}\pi\varepsilon_0}\frac{q}{a^2}$
b. $\frac{q}{8\pi\varepsilon_0 a^2}[\sqrt{2}+1]$
c. $\frac{q}{8\pi\varepsilon_0 a^2}[2\sqrt{2}+1]$
d. $\frac{q}{8\pi\varepsilon_0 a^2}[\sqrt{3}+1]$

12. A point charge q = $-8\ nC$ is placed at origin. Find the electric field vector at the point x = 1.2 m, y = -1.6 m.

a. $\sqrt{2}[1.2\hat{\imath}-1.6\hat{\jmath}]\ NC^{-1}$
b. $-\sqrt{2}[1.2\hat{\imath}-1.6\hat{\jmath}]\ NC^{-1}$
c. $-9[1.2\hat{\imath}-1.6\hat{\jmath}]\ NC^{-1}$
d. $-18\sqrt{2}[1.2\hat{\imath}-1.6\hat{\jmath}]\ NC^{-1}$

13. A force 'F' is acting between two charges in air. If the space between them be completely filled with a medium K=4, the force will be:

a. F
b. $4F$
c. $\frac{F}{4}$
d. $2F$

14. A clock face has charges $-q, -2q, -3q, \ldots -12q$ fixed at the position of the corresponding numerals on the dial. The clock hands do not disturb the net field due to the point charges. Then, at what time does the hour hand point in the direction of the electric field at the centre of the dial?

a. 8: 30
b. 9: 30
c. 10: 30
d. 11: 30

15. Two-point charges q_1 = +9 μC and q_2 = (-1) μC are held 10 cm apart. Where should at third charge +Q be placed from q_2 on the line joining them so that charge Q does not experience any net force?

a. 3 cm
b. 4 cm

c. 5 cm
d. 6 cm

16. Two equal negative charges – q are fixed at points $(0, a)$ and $(0, -a)$ on the y-axis. A positive charge Q is in rest at point $(2a, 0)$ on the x-axis. The Electrostatic force experienced by charge Q will be
    a. $\frac{4qk}{3a^3}$
    b. $\frac{qk}{a}$
    c. $\frac{4qk}{5\sqrt{5}a^2}$
    d. $\frac{4qk}{25a}$

17. Two identical small bodies each of mass m and charge q are suspended from two strings each of length l from a fixed point. This whole system is taken into an orbiting artificial satellite, then find the tension in strings
    a. $\frac{kq^2}{l^2} + 2mg$
    b. $\frac{kq^2}{l^2} + 2mg$
    c. $\frac{kq^2}{l^2}$
    d. $\frac{kq^2}{4l^2}$

18. From a lithium atom, all electrons are removed, then calculate the magnitude of electric field (in N/C) at a distance 1 m from centre of nucleus
    a. 43.2×10^{-10}
    b. 43.2×10^{-18}
    c. 43.2×10^{5}
    d. 43.2×10^{-6}

19. The magnitude of electric field at a distance x from a charge q is E. An identical charge is placed at a distance $2x$ from it. Then the magnitude of the force it experiences due to it is
    a. qE
    b. $2\,qE$
    c. $\frac{qE}{2}$
    d. $\frac{qE}{4}$

20. An infinite number of charges, each q coulomb, are placed along x-axis at x = 1 m, 3 m, 9 m, . .. Calculate the electric field at the point x = 0 due to these charges, if all the charges are of the same sign.
    a. $\frac{1}{4\pi\varepsilon_0}\frac{9q}{8}\ NC^{-1}$
    b. $\frac{1}{4\pi\varepsilon_0}\frac{9q}{10}\ NC^{-1}$
    c. $\frac{1}{4\pi\varepsilon_0}\frac{9q}{7}\ NC^{-1}$
    d. $\frac{1}{4\pi\varepsilon_0}\frac{9q}{5}\ NC^{-1}$

Answer Key

Question Number	1	2	3	4	5	6
Answer Key	(a)	(b)	(a)	(a)	(b)	(a)

Question Number	7	8	9	10	11	12
Answer Key	(b)	(b)	(d)	(b)	(c)	(c)

Question Number	13	14	15	16	17	18	19	20
Answer Key	(c)	(b)	(c)	(c)	(d)	(a)	(d)	(a)

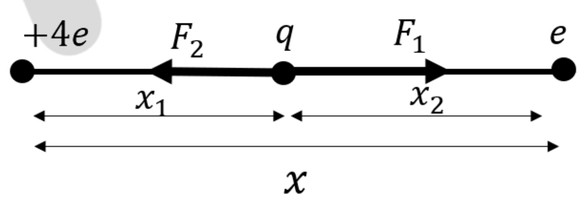
Solutions

1. (a)
   To find the strength of an electric field generated from a point charge
$$E = \frac{KQ}{r^2}$$
$$E = \frac{(9 \times 10^9)(10 \times 10^{-6})}{3^2} = 10000\ \frac{N}{c}$$
2. (b)
   As the electric field lines will come out from positive charge and will go to negative charge

3. (a)
   As, $Q \propto$ No. of electric field line going out or coming in.
   So, $\frac{Q_1}{Q_2} = \frac{\{no.of\ electric\ field\ line\ going\ out\ \ at\ Q_1\}}{\{no.of\ electric\ field\ line\ coming\ in\ \ at\ Q_2\}} = \frac{13}{9}$

4. (a)
   Electrostatic force between two charges will not depend on the presence of other charges in vicinity. Therefore, force of repulsion between q_1 & q_2 will remain 10 N.
   Note: However, the net force on a charge will get affected.

5. (b)



Let, q_1 be $+4e$ and q_2 be $+e$, distance from q_1 be x_1 and distance from q_2 be x_2
For such a case, equilibrium of q can only be achieved in region between the two positive charge. Now,
$$|F_1| = |F_2|$$
$$\frac{1}{4\pi\varepsilon_0}\frac{qq_1}{x_1^2} = \frac{1}{4\pi\varepsilon_0}\frac{qq_2}{x_2^2}$$
$$\frac{x_2}{x_1} = \sqrt{\frac{q_2}{q_1}} = \frac{1}{2}$$
$$\&\ x_2 + x_1 = x$$
$$\Rightarrow x_2 = \frac{x}{3}$$

6. (a)

The electrostatics force of repulsion between the charge q and $(Q-q)$ at separation r is given as

$$F_r = \frac{1}{4\pi\varepsilon_0}\frac{q(Q-q)}{R^2}$$

$$F_r = \frac{1}{4\pi\varepsilon_0}\frac{(qQ-q^2)}{R^2}$$

If F is maximum, then, $\frac{dF}{dq} = 0$

i.e., $\frac{1}{4\pi\varepsilon_0}\frac{(Q-2q)}{R^2} = 0$

as $\frac{1}{4\pi\varepsilon_0 r^2}$ is constant, therefore

$$Q - 2q = 0$$

$$Q = 2q$$

7. (b)

$$\vec{E} = \frac{1}{4\pi\varepsilon_0}\frac{q\hat{r}}{r^2}$$

$$= \frac{9\times 10^9 \times [-4\times 10^{-6}]}{(0.5)^2}\hat{r}$$

$$= [-14.4\times 10^4\ NC^{-1}]\hat{r}$$

8. (b)

The equation for force experienced by two-point charges is

$$F = \frac{kq_1q_2}{r^2}$$

On rearranging the above equation

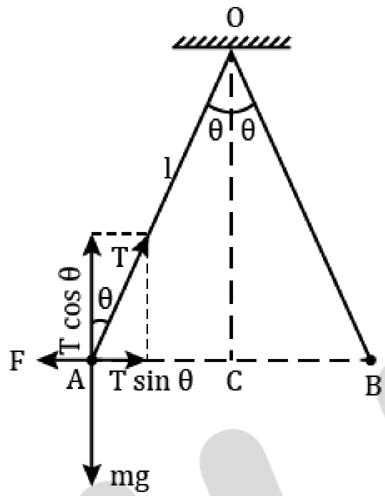
$$q_2 = \frac{Fr^2}{Kq_1}$$

$$q_2 = \frac{(0.04505)(2^2)}{(9\times 10^9)(3\times 10^{-6})} = 6\times 10^{-6}$$

$$q_2 = 6\ \mu C$$

9. (d)

From free body diagram,



$$T \sin\theta = F \ldots (i)$$
$$T \cos\theta = mg \ldots (ii)$$

On dividing equation (i) with equation (ii) we get,

$$\tan\theta = \frac{F}{mg}$$
$$\Rightarrow mg \tan\theta = F \ldots (iii)$$

As we know, $F = \frac{1}{4\pi\epsilon_0}\frac{(q)^2}{r^2} \ldots (iv)$

Where, $r = AB = AC + CB$

AS, $AC = CB$

$$r = 2AC$$
$$AC = l \sin\theta$$

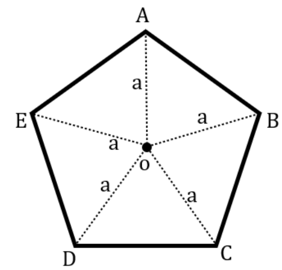
So, $r = 2l \sin\theta$, substitute r in (iv) equation

$$F = \frac{1}{4\pi\varepsilon_0}\frac{(q)^2}{4l^2 \sin^2\theta}$$

On substituting in equation(iii) we get

$$mg \tan\theta = \frac{1}{4\pi\varepsilon_0}\frac{(q)^2}{l^2 \sin^2\theta}$$
$$(4mgl^2 \tan\theta \sin^2\theta)4\pi\varepsilon_0 = q^2$$

10. (b)



If we assume that q charge is placed at all the 5 corners of the given pentagon then, due to its symmetry, the electric field due to all the charges are cancelled out. As a result of which the electric field at O is zero.

Thus, we can write that the vector sum of electric field due to charge A and electric field due to other four charges at the centre of the pentagon should be zero.

$$\overrightarrow{E_A} + \vec{E}_{BCDE} = 0$$

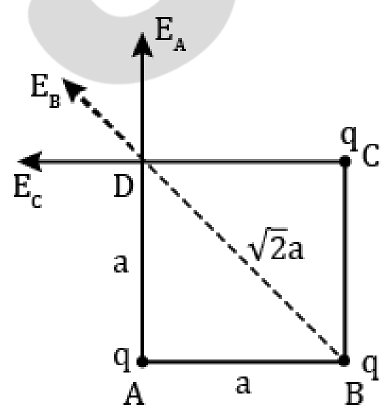
Hence, $\vec{E}_{BCDE} = -\vec{E}_A$

When charge q is removed from A, the net electric field at the centre of the pentagon due to the remaining charges will be

$$|\vec{E}_{BCDE}| = |\vec{E}_A| = \frac{1}{4\pi\varepsilon_0}\frac{q}{a^2}$$

And this will be along OA

11. (c)



Here, $E_A = E_C = \frac{1}{4\pi\varepsilon_0}\frac{q}{a^2}$

The net of these two is

$$\mathrm{E}' = \sqrt{(E_A)^2 + (E_c)^2} = \sqrt{2(E_A)^2} = \sqrt{2} \times \frac{1}{4\pi\varepsilon_0}\frac{q}{a^2}$$

Also,

$$E_B = \frac{1}{4\pi\varepsilon_0}\frac{q}{(\sqrt{2}\,a)^2}$$

Since E' and E_B are along same direction,

$$E_{net} = E' + E_B$$

$$E_{net} = \sqrt{2}\times\frac{1}{4\pi\varepsilon_0}\frac{q}{a^2}+\frac{1}{4\pi\varepsilon_0}\frac{q}{2\,a^2}$$

$$E_{net} = \frac{1}{4\pi\varepsilon_0}\frac{q}{a^2}[\sqrt{2}+\frac{1}{2}]$$

$$E_{net} = \frac{1}{8\pi\varepsilon_0}\frac{q}{a^2}[2\sqrt{2}+1]$$

12. (c)

$$\vec{E} = \frac{1}{4\pi\varepsilon_0}\frac{\text{q}}{r^3}\vec{r}$$

$$\vec{E} = \frac{9\times10^9\times[-8\times10^{-9}]}{((1.2)^2+(1.6)^2)^{3/2}}[1.2\hat{\imath}-1.6\hat{\jmath}]$$

$$\vec{E} = \frac{9\times10^9\times[-8\times10^{-9}]}{(\sqrt{4})^3}[1.2\hat{\imath}-1.6\hat{\jmath}]$$

Simplifying, we get,

$$\vec{E} = -9[1.2\hat{\imath}-1.6\hat{\jmath}]\,NC^{-1}$$

13. (c)

By Coulomb's law, the force between two charges (q_1, q_2) in air is given by

$F = \frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{r^2}$

where r= distance between two charges.

Now the force between two charges (q_1, q_2) in medium with dielectric constant $K = 4$ becomes

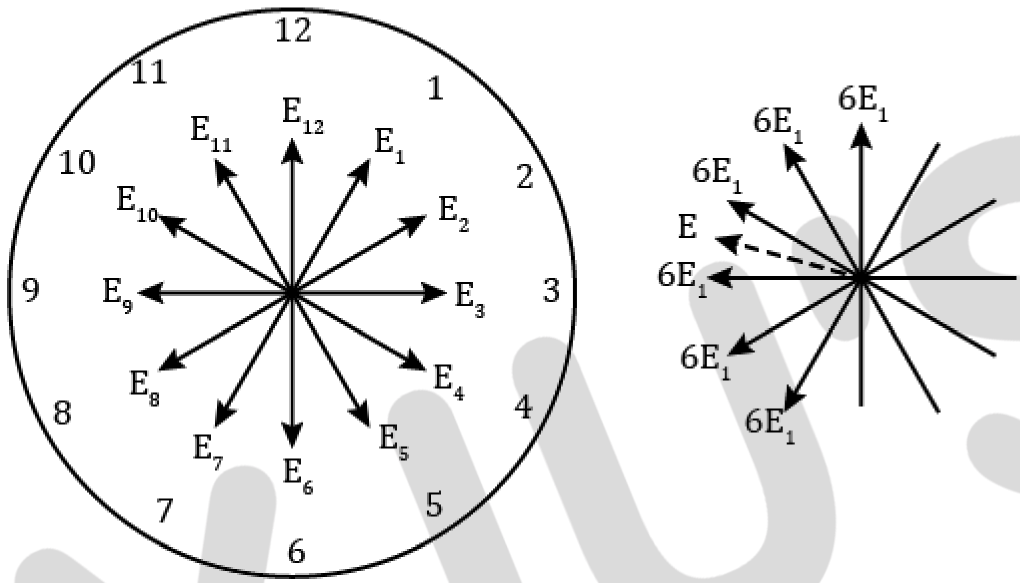
$$F' = \frac{1}{4\pi k\varepsilon_0}\frac{q_1q_2}{\boldsymbol{r^2}}$$

Therefore,

$$F' = \frac{F}{4}$$

14. (b)

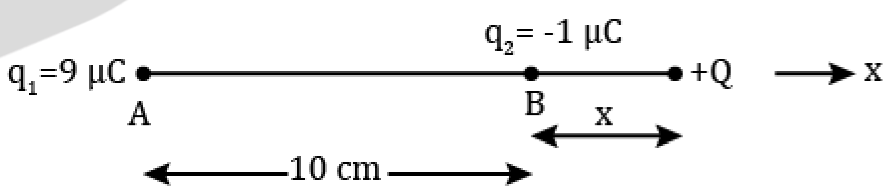
Let, electric field at 1 be E_1. The direction of individual fields and the net field due to opposite corner charges are as depicted below.



We notice that the resultant field will be along angle bisector of field between 9 and 10. Therefore, answer will be 9:30.

15. (c)

Charge Q will not experience any net force if the forces exerted on it by charges q_1 and q_2 are equal and in opposite directions.



It follows from figure that charge Q will not experience any net forces if it lies in the region to the right of AB. Let x be the distance of Q from q_2. Then forces exerted on Q by q_1 and q_2 respectively are

$$F_1 = \frac{q_1 Q\hat{\imath}}{4\pi\varepsilon_0(0.1+x)^2} = \frac{9\times10^{-6}Q\hat{\imath}}{4\pi\varepsilon_0(0.1+x)^2}$$

and

$$F_2 = -\frac{q_2 Q\hat{\imath}}{4\pi\varepsilon_0 x^2} = -\frac{1\times10^{-6}Q\hat{\imath}}{4\pi\varepsilon_0 x^2}$$

Net force on Q $= F_1 + F_2$

Net force on Q = if $F_1 + F_2 = 0$

$\Rightarrow \quad \frac{9\times10^{-6}Q\hat{\imath}}{4\pi\varepsilon_0(0.1+x)^2} - \frac{1\times10^{-6}Q\hat{\imath}}{4\pi\varepsilon_0 x^2} = 0$

$\Rightarrow \quad 9 = \frac{(0.1+x)^2}{x^2}$

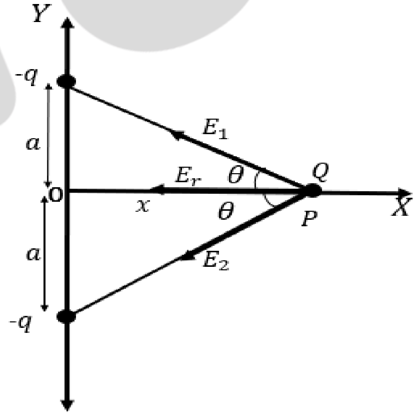
For, x to be positive,

$\Rightarrow \quad 3 = \frac{0.1+x}{x}$

$\Rightarrow \quad$ x = 0.05 m = 5 cm

16. (c)

Let the charge Q be at P, with OP = x. The resultant field F_r is along the x-axis directed towards the origin.



Let, AP = BP = r.

Then,

$$E_1 = E_2 = \frac{q}{4\pi\varepsilon_0 r^2}$$

The resultant field on Q is

$E_r = E_1 \cos\theta + E_2 \cos\theta = \frac{2q}{4\pi\varepsilon_0 r^2}\cos\theta$

Also, $r^2 = a^2 + x^2$

$$E_r = \frac{2q}{4\pi\varepsilon_0}\frac{x}{(a^2+x^2)^{\frac{3}{2}}}$$

As, $x = 2a$

$$E_r = \frac{2q}{4\pi\varepsilon_0}\frac{2a}{(a^2+(2a)^2)^{\frac{3}{2}}} = \frac{4qak}{(5a^2)^{\frac{3}{2}}}$$

$$E_r = \frac{4qk}{5\sqrt{5}a^2}$$

17. (d)

The two bodies are kept in a satellite. Hence, there is no gravity to act on them. So, the only force that acts on the bodies is the coulombs repulsion force. This force repels the two charges until there is maximum separation between them. Now, the maximum separation between the two will be the length of the strings.

So, $r = 2l$

Hence, the tension is the string is due to the force of repulsion.

$$T = F_c = \frac{kq^2}{r^2}$$

$$T = \frac{kq^2}{(2l)^2} = \frac{kq^2}{4l^2}$$

18. (a)

If all electrons are removed, then it will have charge because of 3 proton present in lithium atom. Therefore,

$$q = 3 \times 1.6 \times 10^{-19}\ C$$

Electric field (E)= $\frac{kq}{r^2}$

$$E = \frac{9\times10^9\ \times 3 \times 1.6 \times 10^{-19}}{1} = 43.2 \times 10^{-10}\ \ N/C$$

19. (d)

Given E = $\frac{q}{4\pi\varepsilon_0 x^2}$. Hence the magnitude of the electric field at a distance $2x$ from charge q is

$$E' = \frac{q}{4\pi\varepsilon_0(2x)^2} = \frac{q}{4\pi\varepsilon_0 x^2}\times\frac{1}{4} = \frac{E}{4}$$

Therefore, the force experienced by a similar charge q at a distance $2x$ is

$$F = qE' = \frac{qE}{4}$$

20. (a)

Electric field at origin will be resultant of all electric field.

$$E_0 = E_1 + E_2 + E_3 + \cdots$$

$$E_0 = \frac{kq}{1^2} + \frac{kq}{3^2} + \frac{kq}{9^2} + \cdots$$

$$E_0 = kq\left[\frac{1}{1^2}+\frac{1}{3^2}+\frac{1}{9^2}+\ldots..\right]$$

$$E_0 = \frac{q}{4\pi\varepsilon_0}\left[1+\frac{1}{9}+\frac{1}{81}+\cdots\right]$$

As we know that sum of infinite term of Geometric progression $S_\infty = \frac{a}{(1-r)}$

Where a is the first term and $r = \frac{b}{a} = \frac{\frac{1}{9}}{1} = \frac{1}{9}$

$$E_0 = \frac{q}{4\pi\varepsilon_0}\left[\frac{a}{(1-r)}\right] = \frac{q}{4\pi\varepsilon_0}\left[\frac{1}{(1-\frac{1}{9})}\right]$$

$$E_0 = \frac{9}{8}\frac{q}{4\pi\varepsilon_0}$$