heating and so on.

Numerical problems

1. What is the magnitude of the force of attraction between an iron nucleus bearing charge $q = 26e$ and its innermost electron, if the distance between them is 1×10^{-12} m.

   (6×10^{-3} N)

2. Charges 2 μC, -3 μC, and 4 μC are placed in air at the vertices of an equilateral triangle of sides 10 cm. what is the magnitude of resultant force acting on 4 μC charge?

   (9.5N)

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3. A charge q is placed at the centre of the line joining the two charges, each of magnitude Q. Prove that the system of three charges will be in equilibrium if $q = -Q/4$.

4. Two equal and opposite charges of magnitude 2×10^{-7} C are placed 15cm apart. What is the magnitude and direction of electric intensity (E) at a point mid-way between the charges? What force would act on a proton (charge = $+1.6\times10^{-19}$ C) placed there?

($.64\times10^{6}$ N/C along AB, 1.024×10^{-13} N along AB)

5. Two positive point charges of 15×10^{-10} C and 13×10^{-10}C are placed 12cm apart. Find the work done in bringing the two charges 4 cm closer.

(7.31×10^{-8} J)

6. A hollow sphere is charged to 14μC. Find the potential (a) at its surface (b) inside the sphere (c) at a distance of 0.2m from the surface. The radius of the sphere is 0.3m.

(42×10^{4} V, 42×10^{4} V, 25.2×10^{4} V)

7. If 280 J of work is done in carrying a charge of 2C from a place where the potential is -12V to another place where potential is V, calculate the value of V. (128 V)

8. Calculate the electric potential at the surface of a silver nucleus having radius 3.4×10^{-14} m. The atomic number of silver is 47 and charge on a proton = 1.6×10^{-19}C. (1.99×10^{6} V)

9. The electric field at a point due to a point charge is 26 N/C and the electric potential at that point is 13 J/C. Calculate the distance of the point from the charge and magnitude of charge.

(0.5 m, 0.722×10^{-9} C)

10. Two point charges of 8μC and -4μC are separated by a distance of 10cm in air. At what point on the line joining the two charges is the electric potential zero?

(6.6 cm from 8 μC and, 3.3 cm from −4μ F charge)

11. An electron with an initial speed of $29\times10^{5}ms^{-1}$ is fired in the same direction as a uniform electric field with a magnitude of 80 NC^{-1}. How far does the electron travel before being brought to rest momentarily and turned back?

$K.E = q\Delta V$
$K.E = qEd$
$\frac{1}{2}mv^2 = qEd$

(.299m)

12. Two capacitors of capacitance 4 μF and 8 μF are first connected (a) in series and then (b) in parallel. In each case external source of voltage is 200 V. Calculate in each case the total capacitance, the potential drop across each capacitor, and the charge on each capacitor.

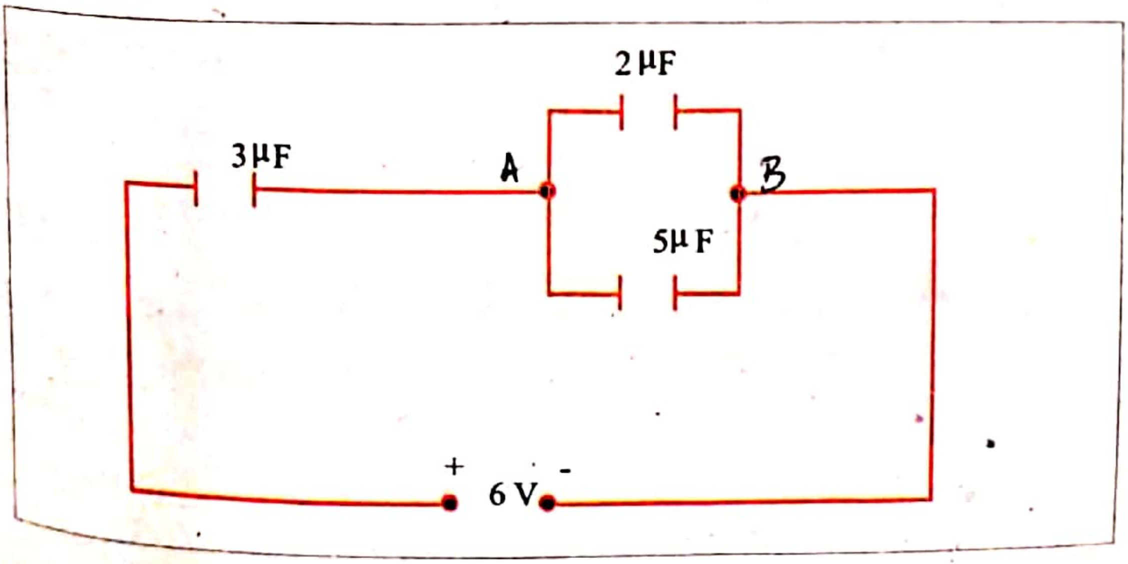
(2.66μF, 5.33×10^{-4}C, 133.2V, 66.6V, 12μF, 200V, .08μC, .16μC)

13. Three capacitors of capacitance 4μF, 6μF and 8μF respectively are connected in series to a 250V d.c. supply. Find (i) the total capacitance (ii) charge on each capacitor and (iii) P.D. across each capacitor.

(1.84 μ F, 460×10^{-6} C, 115 V, 76.6V and 57.7 V)

14. If C_1 = 14μF, C_2 = 20 μF, C_3 = 12μF and the insulated plate of C_1 be at potential of 100V, one plate of C_3 being earthed, what is the potential difference between the plates of C_2, three capacitors being connected in series? (24.4 V)

15. Find the charge on 5μF capacitor in the circuit shown in Fig. .



(9 μ C)

16. Two parallel plate capacitors A and B having capacitance of 2 μF and 6 μF are charged separately to the same potential of 120V. Now positive plate of A is connected to the negative plate of B and the negative plate of A is connected to the positive of B. Find the final charge on each capacitor.

(120 μ C, 360 μ C)

17. A 6μF capacitor is charged to a P.D. of 120V and then connected to an un-charged 4 μF capacitor. Calculate the P.D. across the capacitors.

(72 V)

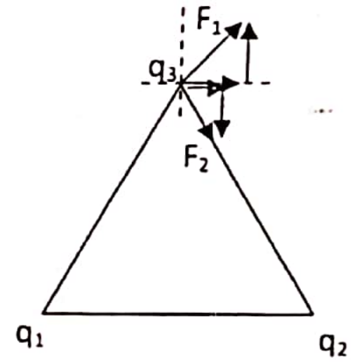
18. Two capacitor of capacitance 8μF and 10 μF respectively are connected in series across a P.D. of 180V. The capacitors are disconnected from the supply and are reconnected in parallel with each other. Calculate the new P.D. and charge on each capacitor.

(88.8 V, 710 μ C, 888 μ C)

Numerical Problems

1. Solution: Charge on iron nucleus, $q_1 = 26e$, Charge on inner most electron, $q_2 = e$
Where $e = 1.6 \times 10^{-19}$ C , Separation, $r = 1 \times 10^{-12}$ m.
Coulomb's constant for vacuum, $k = 9\times 10^{9}$ N m^2 C^{-2},
According to Coulomb's Law:
$F = k\frac{q_1 q_2}{r^2} = 6 \times 10^{-3}$ N

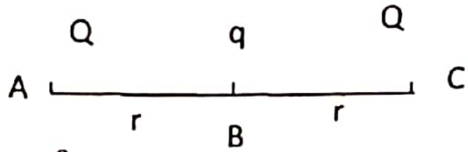
2. Solution: $q_1 = 2\ \mu C$, $q_2 = -3\ \mu C$, $q_3 = 4\ \mu C$
Separation between any two charges , r = 10 cm = 0.1 m,
Magnitude of resultant force on q_3 = F =?
Let F_1 be the force on q_3 due to q_1 and is given by,
$F_1 = k\frac{q_1 q_3}{r^2} = 7.2$ N
similarly, Let F_2 be the force on q_3 due to q_2 and is given by,
$F_2 = k\frac{q_2 q_3}{r^2} = -10.8$ N, the negative sign shows that the force is attractive, and its direction is correctly represented in the diagram.
Now resolve F_1 and F_2 into its components.



For F_1 :-
$F_{1x} = F_1 \cos 60^\circ = 3.6$ N
$F_{1y} = F_1 \sin 60^\circ = 6.24$ N
For F_2 :-
$F_{2x} = F_2 \cos 60^\circ = 5.4$ N
$F_{2y} = F_2 \sin 60^\circ = 9.35$ N

Then, in the light of the diagram, $F_x = F_{1x} + F_{2x} = 9$ N
and $F_y = F_{1y} - F_{2y} = -3.11$ N
Now magnitude of $F = \sqrt{F_x^2 + F_y^2} = \sqrt{(9)^2 + (-3.11)^2} = \sqrt{90.67} = 9.52$ N

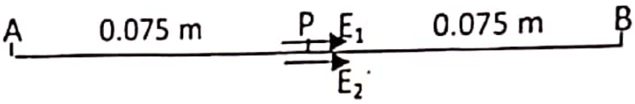
3. Solution: Let two equal charges of magnitude Q, are placed apart 2r, at points A and C, as shown. Let q is a charge placed at mid point B. In order to prove that $q = -\frac{Q}{4}$, for which the system of these charges is in equilibrium, let we focus on charge placed at point A. Let F_1 be the force on Q (at A) due to q (at B). Let F_2 be the force on Q (at A) due to Q (at C).
Then, according to the statement of the problem, $F_1 + F_2 = 0$ ---> (1)
To find F_1 and F_2, we use coulomb's law.



$F_1 = k\frac{Q\,q}{r^2}$, and $F_2 = k\frac{Q\,Q}{(2r)^2}$
Therefore, Eq. 1 => $k\frac{Q\,q}{r^2} + k\frac{Q\,Q}{(2r)^2} = 0$ => $k\frac{Q\,q}{r^2} = -k\frac{Q\,Q}{(2r)^2}$ => $q = -\frac{Q}{4}$ Proved

4.Solution:-

$q_1 = +2\ \mu C$ and $q_2 = -2\ \mu C$, separation between the two charges = 15 cm = 0.15 m
Let P be the mid-point. Let E.F. intensity at P due to q_1 and q_2 respectively are E_1 and E_2 . Their correct directions are represented in the diagram below.



Thus , $E_1 = k\frac{q_1}{r^2}$ = 3.2×10^5 N/C
and $E_2 = k\frac{q_2}{r^2}$ = 3.2×10^5 N/C (the negative sign has compensated by representing the direction)
As E_1 and E_2 are in same direction therefore, net E.F. Intensity,
$E = E_1 + E_2 = 6.4 \times 10^5$ N/C = 0.64×10^6 N/C, from A to B
To find the magnitude of force on a proton placed at mid-point, we know that charge on proton is
$q = 1.6 \times 10^{-19}$ C
Let F be the net force, then $F = Eq = 1.024 \times 10^{-13}$ N from A to B

5. Solution:

$q_1 = 15 \times 10^{-10}$ C , $q_2 = 13 \times 10^{-10}$ C, Initially separated by a distance, r_2 = 12 cm = 0.12 m
final separation between charges, r_1 = 8 cm = 0.08 m
As we know that in an electric field work done appears as change in electric P.E (ΔU), therefore,
$W = (\Delta U) = k\, q_1\, q_2\left(\frac{1}{r_1} - \frac{1}{r_2}\right) = 7.31 \times 10^{-8}$ J

6. Solution:

Charge on the sphere, $q = 14\ \mu C = 14 \times 10^{-6}$ C, Radius of the sphere, r = 0.3 m
The solution for part (a) and part (b) is the same because we know that electric potential remains constant throughout the volume of a conducting sphere.
Thus for both parts, $V = k(\frac{q}{r}) = 42 \times 10^4$ V
Part (c): For a point which is r_1 = 0.2 m away from the surface of the sphere
$V = k(\frac{q}{r + r_1}) = 25.2 \times 10^4$ V

7.Solution:

Charge to be moved, q = 2 C, Electric potential at point B, V_B = - 12 V
Electric potential at point A, V_A = V = ?, W.Done from B to A, $W_{B\to A}$ = 280 J
As we know that P.d between A and B is , $\Delta V = \frac{W_{B\to A}}{q} = \frac{280}{2}$ = 140 V
As , P.d = (High voltage) - (low voltage) = $V_A - V_B$
or $V_A = \Delta V + V_B$ = 140 +(-12) = 128 V

8. Solution:

Radius of silver nucleus, $r = 3.4 \times 10^{-14}$ m, Atomic number of silver, Z = 47
charge on each proton, $q = 1.6 \times 10^{-16}$ C, total charge on silver nucleus, $Q = Z\,q = 75.2 \times 10^{-19}$ C
Thus electric potential at the surface of the silver nucleus, V (kQ)/r = 1.99×10^6V

9. Solution:

(a) E = V/r , r = V/E = 13/26 = 0.5 m
(b) As we know, V = (kq)/r ⇒ q = (Vr)/k = 0.722×10^{-9} C

10.Solution:

$q_1 = 8\ \mu C$, $q_2 = -4\ \mu C$, separation between the charges, $r = 10$ cm $= 0.1$ m

Let the distance of the point of zero potential is x m from q_1 and (r - x) m from q_2 on the line between them. Let V_1 = electric potential at that point due to q_1

V_2 = electric potential at that point due to q_2

Thus according to the statement of the question, $V_1 + V_2 = 0$

$[(kq_1)/x\ ] + [\ (kq_2)/(r - x)] = 0 \Rightarrow [(kq_1)/x\ ] = -\ [\ (kq_2)/(r - x)]$

$\frac{q_1}{x} = -\ \frac{q_2}{(r-x)} \Rightarrow \frac{8\ \mu C}{x} = -\ (\frac{-4\ \mu C}{r-x}) \Rightarrow \frac{2}{x} = \frac{1}{r-x} \Rightarrow x = 2r - 2x \Rightarrow 3x = 2r$

$\Rightarrow x = 2r/3 = 0.0666$ m $= 6.6$ cm

hence the point is 6.6 cm away from q_1 and $(r - x) = 10 - 6.6 = 3.3$ cm from q_2 on the line joining them.

11. Solution:

Loss in K.E = w. done By electric field = qV = qEd

$\Rightarrow$ d = (loss in K.E)/ qE $= (\frac{1}{2} m v^2)/qE = 0.299$ m

12. Solution:

$C_1 = 4\ \mu F$, $C_2 = 8\ \mu F$; $V = 200V$

(a) C_{eq} = ? in series

$C_{eq} = \frac{C_1 C_2}{C_1 - C_2} = 2.6 \times 10^{-6}$ F

$Q = C_{eq} V = 5.33 \times 10^{-4}$ C

As we know that in series combination , p.dp across different capacitors is different.

$V_1 = Q/ C_1 = 133.2$ V

$V_2 = Q/C_2 = 66.6$ V

(b) C_{eq} = ? in parallel

$C_{eq} = C_1 + C_2 = 12 \times 10^{-6}$ F

in parallel the p.d. across each capacitor is same, i.e. 200 V

in parallel charge on each capacitor will be different

$Q_1 = C_1 V = 8 \times 10^{-4}$ C

$Q_2 = C_2 V = 16 \times 10^{-4}$ C

13. Solution:

$C_1 = 4\ \mu F$, $C_2 = 6\ \mu F$, $C_3 = 8\ \mu F$, $V = 250$ V

(a) C_{eq} = ? in series.

$$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} = \frac{1}{4} + \frac{1}{6} + \frac{1}{8} = \frac{6+4+3}{24} = \frac{13}{24}$$

$\Rightarrow C_{eq} = 1.846 \times 10^{-6}$ F

(b) in series combination charge on each capacitor is same, as total charge

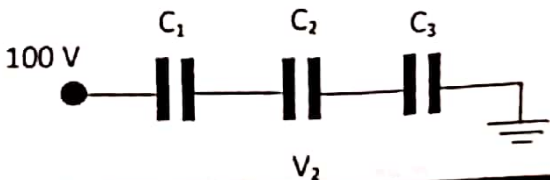
$Q_1 = Q_2 = Q_3 = Q = C_{eq} V = 462 \times 10^{-6}$ C

(c) in series the p.d. across each capacitor is different.

$V_1 = Q/C_1 = 115.5$ V

$V_2 = Q/C_2 = 77$ V

$V_3 = Q/C_3 = 57.7$ V



14. Solution:

$C_1 = 14\ \mu F$, $C_2 = 20\ \mu F$, $C_3 = 12\ \mu F$, $V = 100$ V,

p.d. across C_2, V_2 = ?
In series combination, p.d. across each capacitor is different. therefore,

$V_2 = \frac{Q_{total}}{C_2}$ --> (1)

To find total charge, first we need to determine the C_{eq} .

$$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$$

$\Rightarrow C_{eq} = 4.88 \times 10^{-6}$ F

Now , $Q_{total} = C_{eq} V = 488 \times 10^{-6}$ C

thus from eq. (1) , $V_2 = (488 \times 10^{-6}\text{ C})/ (4.88 \times 10^{-6}\text{ F}) = 24.4$ V

15. solution

Let, $C_1 = 3\ \mu F$

$C_2 = 2\ \mu F$ and $C_3 = 5\ \mu F$

Let C_{AB} the net/total capacitance between A and B, in fig. 1. Then,

$C_{AB} = 7\ \mu F$

Now the circuit can be re-draw, as shown in fig.2.

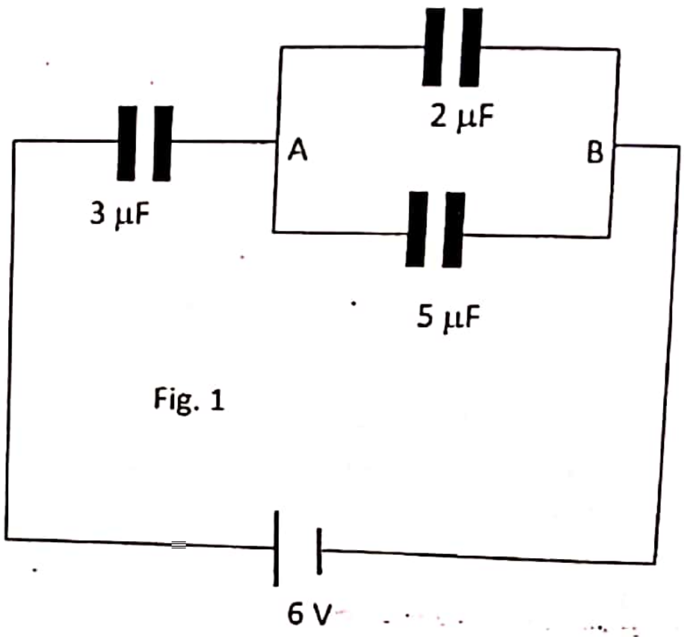


Fig. 1

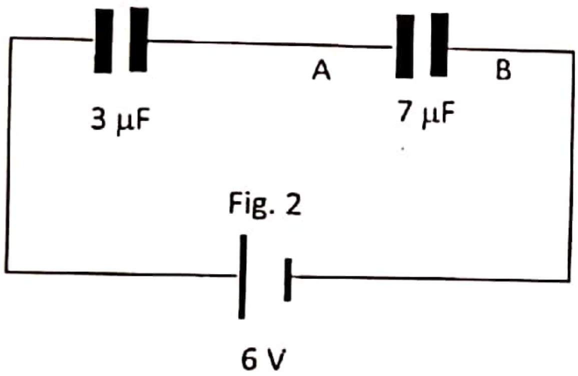


Fig. 2

Let C_{eq} be the net capacitance of fig.2, then $C_{eq} = \frac{C_1 C_{AB}}{C_1 + C_{AB}} = \frac{3 \times 7}{3 + 7} = \frac{21}{10} = 2.1\ \mu F$

Let Q be the total charge stored in circuit shown in fig.2

$Q = C_{eq} V = 12.6\ \mu C$

Thus charge stored on C_{AB} will also be 12.6 µC. Now p.d. between A and B is,

$V_{AB} = \frac{Q}{C_{AB}} = \frac{12.6}{7} = 1.8$ V

Now charge on C_3, $Q_3 = C_3 V_{AB} = 5\ \mu F \times 1.8\ V = 9\ \mu C$

$q_3 = 9\ \mu C$

11.16 Two parallel plate capacitors A and B having capacitance of 2 μF and 6 μF are charged separately to the same potential of 120 V. Now positive plate of A is connected to the negative plate of B and the negative plate of A is connected to the positive of B. Find the final charge on each capacitor.

Solution

$C_1 = 2\ \mu F$ $\quad C_2 = 6\ \mu F$ $\quad V = 120\ V$ $\quad Q_1 = Q_2 = ?$

Initial charge on A; $\quad q_1 = C_1 V = (2 \times 10^{-6})(120) = 240\ \mu C$

Initial charge on B; $\quad q_2 = C_2 V = (6 \times 10^{-6})(120) = 720\ \mu C$

So net capacitance C_{eq} is

$$C_{eq} = C_1 + C_2 = 8\ \mu F$$

When they are connected, net charge

$$Q = q_2 - q_1 = (720 - 240)\ \mu C$$

$$Q = 480\ \mu C$$

New potential difference

$$V_n = \frac{Q}{C_{eq}} = \frac{480 \times 10^{-6}}{8 \times 10^{-6}} = 60\ V$$

Now final charge on A;

$$Q_1 = C_1 V_n = (2 \times 10^{-6})(60) = 120\ \mu C$$

And final charge on B;

$$Q_2 = C_2 V_n = (6 \times 10^{-6})(60) = 360\ \mu C$$

11.17 A 6μF capacitor is charged to a P.D. of 120 V and then connected to an un-charged 4μF capacitor. Calculate the P.D. across the capacitors.

Solution

$C_1 = 6 \times 10^{-6} F$ $\quad V_1 = 120\ V$ $\quad C_2 = 4 \times 10^{-6} F$ $\quad V = ?$ (Parallel)

$$Q = C_1 V_1 = (6 \times 10^{-6})(120) = 720\ \mu C$$

When capacitors are connected in parallel then total capacitance

$$C_{eq} = C_1 + C_2 = (6 + 4)\ \mu F = 10\ \mu F$$

As both are in parallel so P.D across both will be same, given by equation

$$V = \frac{Q}{C} = \frac{720 \times 10^{-6}}{10 \times 10^{-6}} = 72\ V$$

11.18 Two capacitors of capacitance 8μF and 10μF respectively are connected in series across a P.D. of 180V. The capacitors are disconnected from the supply and

are reconnected in parallel with each other. Calculate the new P.D. and charge on each capacitor.

Solution

$C_1 = 8 \times 10^{-6}$ F $\quad$ $C_2 = 10 \times 10^{-6}$ F $\quad$ V = 180 V (Series)

$V' = ?$ $q_1 = ?$ and $q_2 = ?$ when connected in parallel & supply removed

In series combination, equivalent capacitance C_{eq} is

$$C_{eq} = \frac{C_1 C_2}{C_1 + C_2} = \frac{8 \times 10 \times 10^{-12}}{(8 + 10)\, 10^{-6}} = 4.4\ \mu F$$

Now total charge

$$Q = C_{eq} \times V = (4.4 \times 10^{-6}) \times 180 \approx 800\ \mu C$$

Since they are connected in series so

$$q_1 = q_2 = Q = 800\ \mu C$$

Total charge q_{tot} in parallel combination is sum of charges q_1 & q_2

So

$$q_{total} = q_1 + q_2 = (800+800)\ \mu C = 1600\ \mu C$$

When capacitors are connected in parallel, equivalent capacitance is

$$C_{eq} = C_1 + C_2 = (8 + 10)\ \mu F = 18\ \mu F$$

Total charge q_{tot} in parallel combination is distributed between two capacitors to have a common P.D. so new potential difference (V') across the capacitors is

$$V' = \frac{\text{total charge } (q_{tot})}{\text{total capacitance } (C_{eq})} = \frac{1600 \times 10^{-6}}{18 \times 10^{-6}} = 88.89\ V$$

New charge on 8 μF capacitor is

$$Q_1 = C_1 V' = (8\mu F)(88.89) = 711\ \mu C$$

New charge on 10 μF capacitor

$$Q_2 = C_2 V' = (10\mu F)(88.89) = 888.9\ \mu C$$