Unit - I
1.7 Electrostatics

Dr.Santhosh.T.K.

Smart Grid

Power grid → POSOCO

5 regional grid

↓

one grid

→ Southern → HVDC

Grid + communication + Automation } Smart grid

4 Diesel gen } 1 Turned off

↓

Comp Block + Hostel

↓

load ↓

ATC

↓

17%

SASTRA DEEMED TO BE UNIVERSITY

Syllabus

UNIT – I **10 Periods**

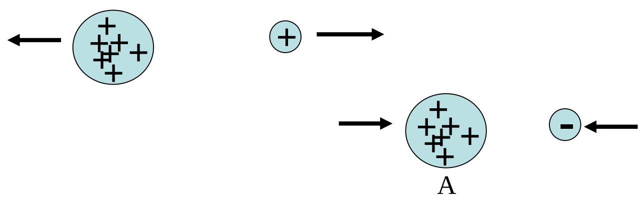
Introduction and Basic Concepts: Concept of Potential difference, voltage, current - Fundamental linear passive and active elements to their functional current-voltage relation - Terminology and symbols in order to describe electric networks - Concept of work, power, energy and conversion of energy- Principle of batteries and application.

Principles of Electrostatics: Electrostatic field - electric field intensity - electric field strength - absolute permittivity - relative permittivity - capacitor composite – dielectric capacitors - capacitors in series & parallel - energy stored in capacitors - charging and discharging of capacitors.

SASTRA DEEMED TO BE UNIVERSITY

The Electric Field

Between two charged bodies there is a force, F, of attraction or repulsion:

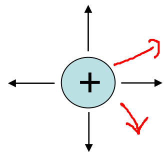


We don't understand why; we can only say this is what happens.

We can think of a charged body as *changing the nature of the space surrounding it*.

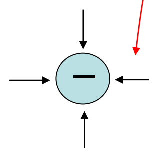
Direction of the Electric Field

Outward (away) from a positive charge



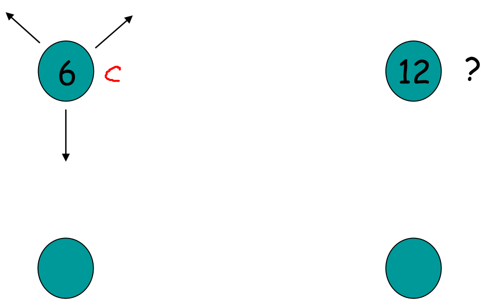
These are called "field arrows"

Inward (towards) a negative charge



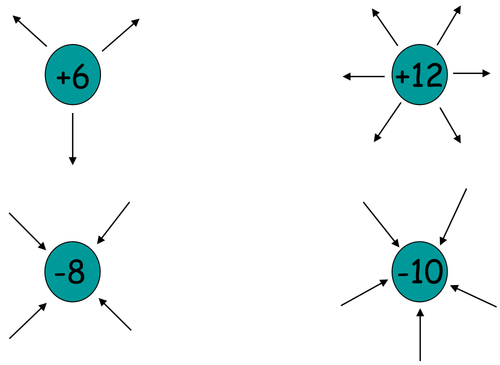
Direction of the Electric Field

We draw the number of arrows proportional to the charge…more charge, more arrows. Say the charges are in "μCoulombs" (that's micro-coulombs, or 10^{-6} Coulombs)



Direction of the Electric Field

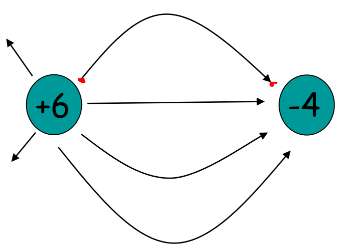
We draw the number of arrows proportional to the charge…more charge, more arrows. Say the charges are in “μCoulombs” (that’s micro-coulombs, or 10^{-6} Coulombs)



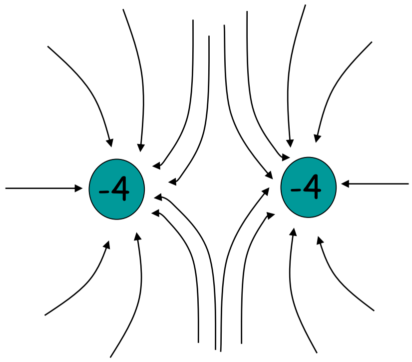
Direction of the Electric Field

When charges get near each other, these fields interact

For unlike charges, the arrows go from the positive charge to the negative charge:



For like particles the arrows are repelled:



The field arrows never cross in either case

Electric Field Intensity (Cont'd)

It becomes convenient to define electric field intensity $\mathbf{E}_1$ or force per unit charge as:

$$\mathbf{E}_1 = \frac{\mathbf{F}_{12}}{Q_2}$$

This field from charge Q_1 fixed at origin results from the force vector $\mathbf{F}_{12}$ for any arbitrarily chosen value of Q_2

SASTRA DEEMED TO BE UNIVERSITY

Electric Field Intensity (Cont'd)

$F = \frac{q_1 q_2}{4\pi\epsilon r^2}$

Coulomb's law can be rewritten as

$E = \frac{F}{q} = \frac{q}{4\pi\epsilon r^2}$

$$\boxed{\mathbf{E} = \frac{Q}{4\pi\varepsilon_0 |\mathbf{R}|^2}\mathbf{a}_R}$$

to find the **electric field intensity** at any point in space resulting from a fixed charge Q.

SASTRA DEEMED TO BE UNIVERSITY

Example 2

Find **E** at (0,3,4) m in cartesian coordinates due to a point charge Q =0.5μC at the origin.

Solution to Example 2

$$\mathbf{R} = 3\mathbf{a}_y + 4\mathbf{a}_z \qquad \mathbf{a}_R = (3\mathbf{a}_y + 4\mathbf{a}_z)/5$$

$$R = 5 \qquad = 0.6\mathbf{a}_y + 0.8\mathbf{a}_z$$

$$\mathbf{E} = \frac{0.5\times10^{-6}}{4\pi(10^{-9}/36\pi)(5)^2}(0.6\mathbf{a}_y + 0.8\mathbf{a}_z)$$

$E =$

unit vector

Thus $[\mathbf{E}] = 180V/m$ in the direction $\mathbf{a}_R = 0.6\mathbf{a}_y + 0.8\mathbf{a}_z$

SASTRA DEEMED TO BE UNIVERSITY

Electric Field Intensity (Cont'd)

If there are N charges, $Q_1, Q_2 \ldots Q_N$ located respectively at point with position vectors $r_1, r_2 \ldots r_N$ the electric field intensity at point r is:

$$\mathbf{E} = \frac{Q_1}{4\pi\varepsilon_0 |\mathbf{r}-\mathbf{r}_1|^2} \frac{(\mathbf{r}-\mathbf{r}_1)}{|\mathbf{r}-\mathbf{r}_1|} + \ldots \frac{Q_N}{4\pi\varepsilon_0 |\mathbf{r}-\mathbf{r}_N|^2} \frac{(\mathbf{r}-\mathbf{r}_N)}{|\mathbf{r}-\mathbf{r}_N|}$$

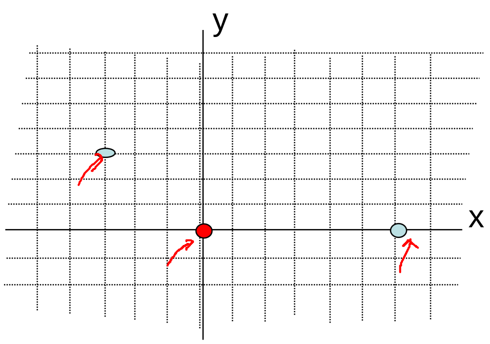
$$\boxed{\mathrm{E} = \frac{1}{4\pi\varepsilon_0} \sum_{k=1}^{N} \frac{Q_k (\mathrm{r}-\mathrm{r}_k)}{|\mathrm{r}-\mathrm{r}_k|^3}}$$

SASTRA DEEMED TO BE UNIVERSITY

Superposition of forces from two charges

Blue charges fixed , negative, equal charge (-q)

What is force on positive red charge +q ?



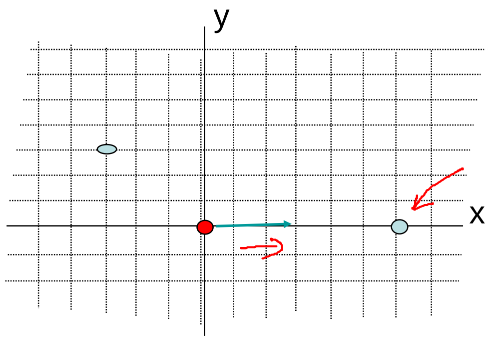
SASTRA
DEEMED TO BE UNIVERSITY

Superposition of forces from two charges

Blue charges fixed , negative, equal charge (-q)

What is force on positive red charge +q ?

Consider effect of each charge separately:



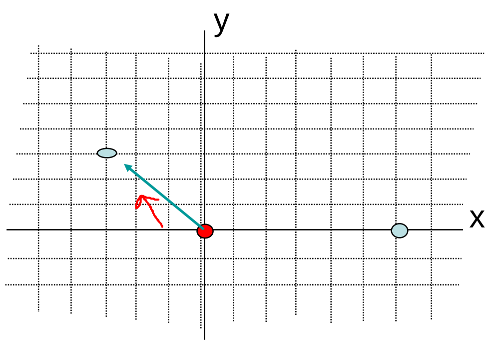
SASTRA
DEEMED TO BE UNIVERSITY

Superposition of forces from two charges

Blue charges fixed , negative, equal charge (-q)

What is force on positive red charge +q ?

Take each charge in turn:

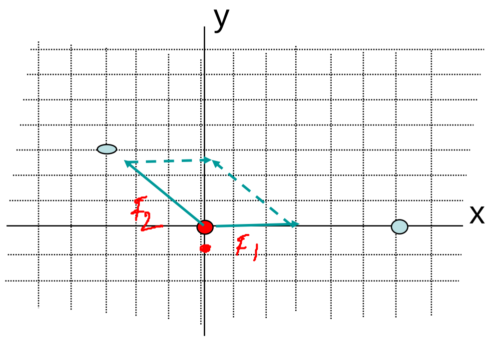


Superposition of forces from two charges

Blue charges fixed , negative, equal charge (-q)

What is force on positive red charge +q ?

Create vector sum:

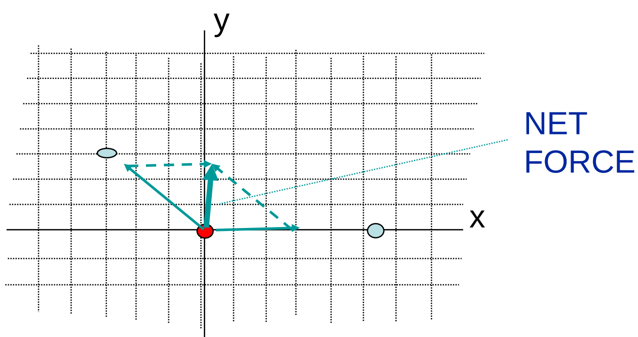


Superposition of forces from two charges

Blue charges fixed , negative, equal charge (-q)

What is force on positive red charge +q ?

Find resultant:



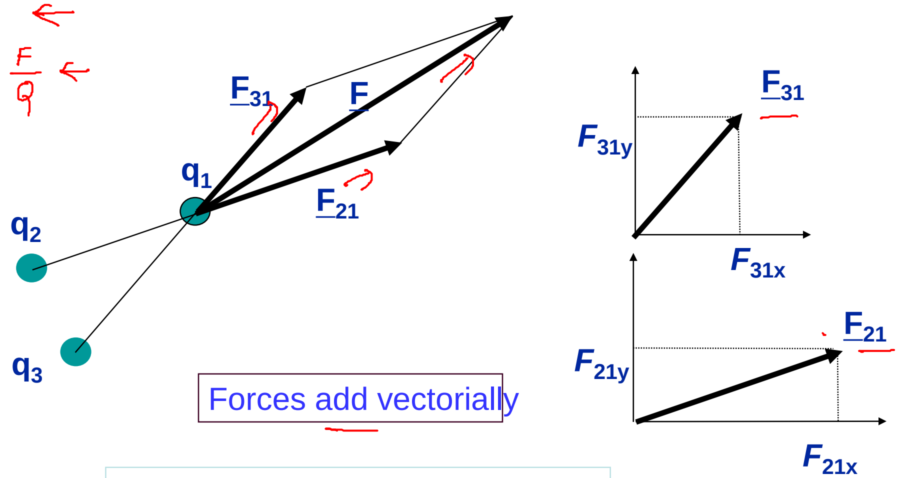
When a number of charges are present, the total force on a given charge is equal to the vector sum of the forces due to the remaining other charges on the given charge.

SASTRA DEEMED TO BE UNIVERSITY

Superposition Principle

$F \leftarrow$

$E = \frac{F}{Q} \leftarrow$



$$\underline{F} = (F_{21x} + F_{31x})\,\underline{x} + (F_{21y} + F_{31y})\,\underline{y}$$

SASTRA DEEMED TO BE UNIVERSITY

Just as we defined a gravitational field, we define an "electric field" in a similar manner:

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

$$mg = \frac{GmM}{r^2}$$

$$g = \frac{GM}{r^2}$$

Practical Applications

- Microwave ovens
- Motor
- Storage (capacitor)
- Healing (IR)
- Identification

This is the gravitational field (Earth = 9.8 m/s² or 9.8 N/kg)

Just as we defined a gravitational field, we define an "electric field" in a similar manner:

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

$$mg = \frac{GmM}{r^2}$$

$$g = \frac{GM}{r^2}$$

$$F = \frac{k|qQ|}{r^2}$$

This is the gravitational field (Earth = 9.8 m/s^2 or 9.8 N/kg)

SASTRA
DEEMED TO BE UNIVERSITY
(U/S 3 OF THE UGC ACT, 1956)
THINK MERIT | THINK TRANSPARENCY | THINK SASTRA

Just as we defined a gravitational field, we define an "electric field" in a similar manner:

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

$$mg = \frac{GmM}{r^2}$$

$$g = \frac{GM}{r^2}$$

$$F = \frac{k|qQ|}{r^2}$$

$$q(?) = \frac{k|qQ|}{r^2}$$

$$E = \frac{F}{q}$$

$$F = qE$$

This is the gravitational field (Earth = 9.8 m/s^2 or 9.8 N/kg)

SASTRA DEEMED TO BE UNIVERSITY

Just as we defined a gravitational field, we define an "electric field" in a similar manner:

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

$$mg = \frac{GmM}{r^2}$$

$$g = \frac{GM}{r^2}$$

$$F = \frac{k|qQ|}{r^2}$$

$$q(E) = \frac{k|qQ|}{r^2}$$

This is the gravitational field (Earth = 9.8 m/s² or 9.8 N/kg)

SASTRA DEEMED TO BE UNIVERSITY

Just as we defined a gravitational field, we define an "electric field" in a similar manner:

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

$$mg = \frac{GmM}{r^2}$$

$$g = \frac{GM}{r^2}$$

$$F = \frac{k|qQ|}{r^2}$$

$$q(E) = \frac{k|qQ|}{r^2}$$

$$E = \frac{k|Q|}{r^2}$$

Electric field

This is the gravitational field (Earth = 9.8 m/s² or 9.8 N/kg)

SASTRA
DEEMED TO BE UNIVERSITY

The general equation for an ELECTRIC FIELD is:

$$E = \frac{k|Q|}{r^2}$$

$$\frac{Newtons}{Coulomb} = \frac{N}{C}$$

(compare this to the equation for the gravitational field)

SASTRA
DEEMED TO BE UNIVERSITY

Notice that for gravity, F = mg

We see that in electrostatics, F = qE

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

$$mg = \frac{GmM}{r^2}$$

$$g = \frac{GM}{r^2}$$

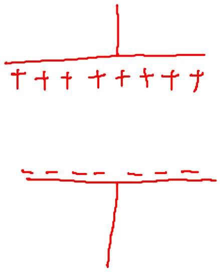
$$F = \frac{k|qQ|}{r^2}$$

$$q(E) = \frac{k|qQ|}{r^2}$$

$$E = \frac{k|Q|}{r^2}$$

SASTRA DEEMED TO BE UNIVERSITY

Capacitors.



F / MF

Ultracapacitors → Energy, → ↓ power

F 10F / 50F

Discharge

→ Energy Storage → gadgets

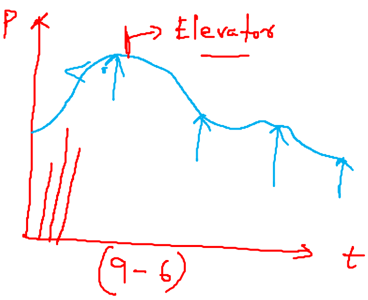
Energy Buffer → Electric vehicle
→ Domestic

SASTRA DEEMED TO BE UNIVERSITY

Hybrid → HEV → Engine + Battery (Prius)
→ PHEV → grid

Apartment
↳ 20 homes → Power demand (month)

Peak → FN (6-9)
→ AN (6-9)



Swan } Solar power + UC

3 L → 6pm
1 F →
1 mixer → 7am
1 AC → 10pm
1 Refrigerator → x
1 TV → 6pm
1 Water heater → 7am
1 Mobile charger → 6pm

EV } Battery + UC } kona
→ Li-ion

SASTRA DEEMED TO BE UNIVERSITY (U/S 3 OF THE UGC ACT, 1956)
THINK MERIT | THINK TRANSPARENCY | THINK SASTRA

Summary

Electrostatics
- F
- E
- capacitor
  - Tradition
  - UC

} E.V.

EV → Zero emission
- Well to wheel