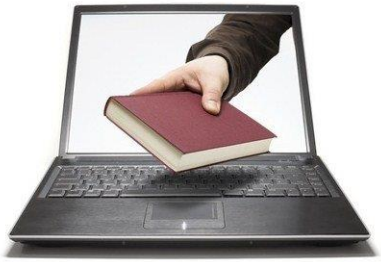
ELEKTROSTATIKA

FIZIKA KAFEDRASI



Fizika I

9 – ma’ruza

2020

Ma’ruza rejasi

- Elektr o‘zaro ta’sir.
- Elektr zaryadi.
- Kulon qonuni.
- Elektrostatik maydon va uning kuchlanganligi. Superpozisiya prinsipi.
- Elektr induksiya vektori va uning kuch chiziqlari.
- Elektr induksiya oqimi.
- Ostrogradskiy – Gauss teoremasi.

Elektr o‘zaro ta’sir

Zaryadlangan va magnitlangan jismlar, shuningdek elektr toki oqayotgan jismlar orasida *elektromagnit kuchlar* deb ataluvchi o‘zaro ta’sir kuchlari mavjuddir. Jismlar orasidagi bu o‘zaro ta’sir *elektromagnit maydon* deb ataluvchi o‘ziga xos vositachi materiya orqali uzatiladi. O‘zaro ta’sir kuchlari oraliq muhit orqali uzatiladi, tarqalish tezligi yorug‘likning vakuumdagi tezligiga yaqin bo‘ladi.

Zaryadlangan qo‘zg‘almas jism atrofidagi fazoda ekektr maydoni hosil bo‘ladi. Harakatlanayotgan zaryad atrofida qo‘shimcha magnit maydoni ham hosil bo‘ladi.

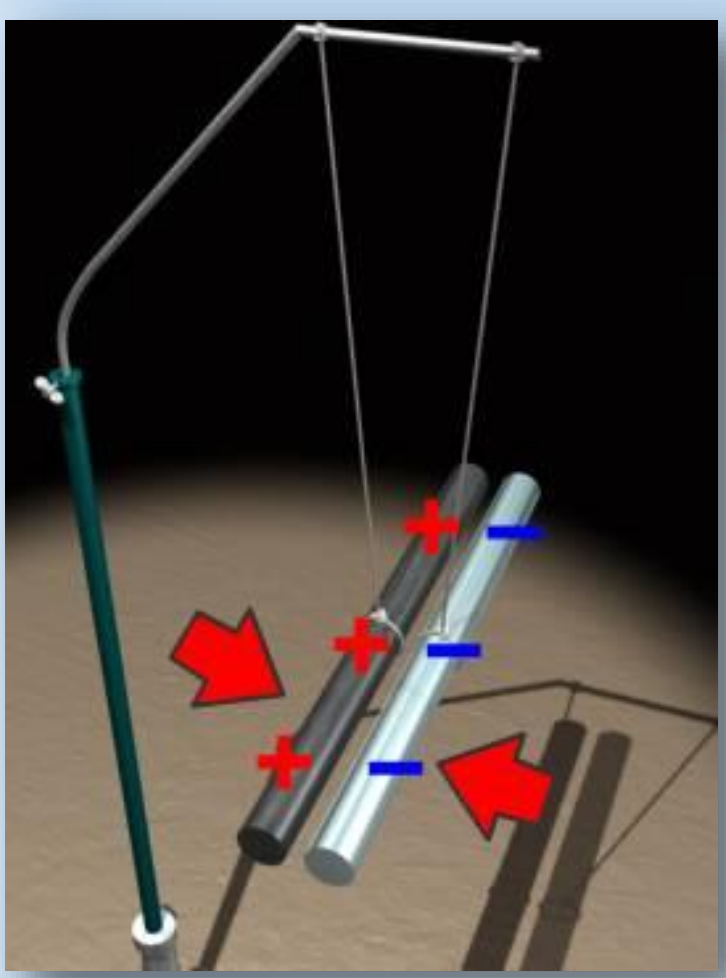
Odatda elektr maydon unga kiritilgan boshqa zaryadlangan jismga ta’siri orqali namoyon bo‘ladi, ammo bu elektr maydoni zaryadlangan jism joylashtirilmaganda ham mavjuddir.

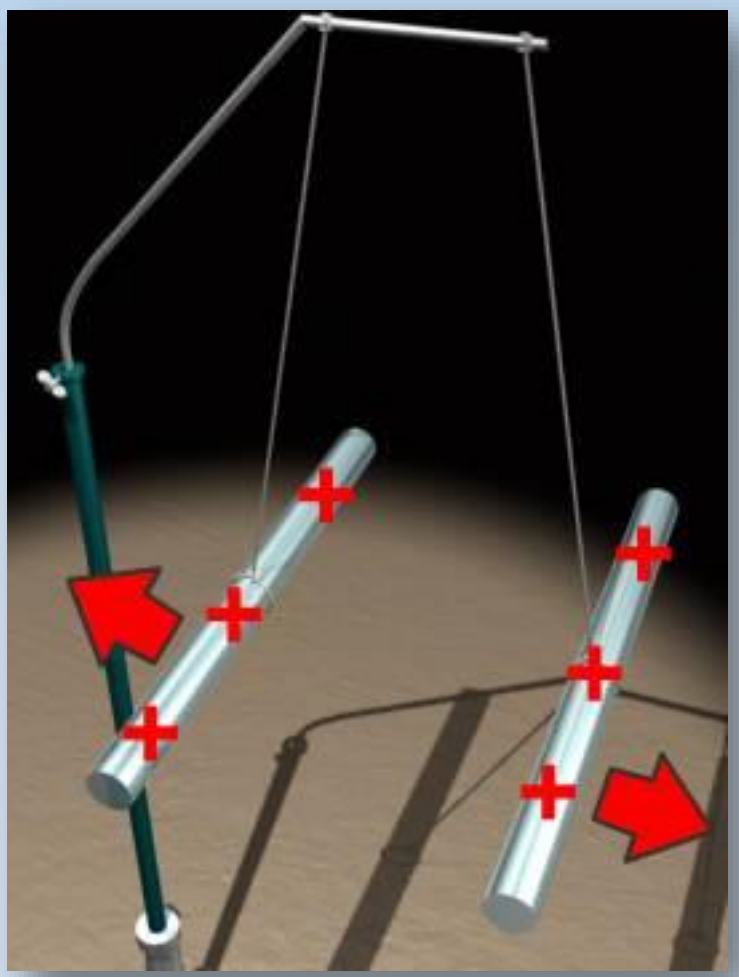
Elektr zaryadi

1. Musbat va manfiy deb shartli atalgan ikki turdagi elektr zaryadlari mavjuddir. Zaryadlar bir jismdan ikkinchisiga uzatilishi mumkin.
2. Elektr zaryadi berilgan jismning daxlsiz xususiyati emas, chunki shu jism turli holatlarda har xil zaryadlarga ega bo‘lishi mumkin.
3. Bir xil ishorali zaryadlar itarishadi, turli ishorali zaryadlar tortishadi. Qo‘zg‘almas zaryad o‘z atrofida elektr maydon xosil qilishi va u orqali ta’sirlashishi bilan o‘zini namoyon qiladi.

$$e = -1,6 \cdot 10^{-19} C$$ - elementar zaryad

$$q = ne \quad n = 1, 2, 3...$$ - zaryadning diskretligi





Elektr zaryadining saqlanish qonuni

Elektrdan ajratilgan tizimlarda zaryadlar yig‘indisi o‘zgarmas bo‘ladi va bu *zaryadlarning saqlanish qonuni* deb ataladi.

$$\sum q_i = const$$

Elektr zaryadi sanoq tizimiga nisbatan invariantdir, ya’ni tinch holatda yoki harakatda bo‘lishiga bog‘liq emas.

***Nuqtaviy zaryad* deb, shunday zaryadlangan jismga aytiladiki, unung o‘lchamlari boshqa zaryadlangan jismlargacha bo‘lgan masofaga nisbatan sezilarli darajada kichikdir.**

Zaryadlarning hajmiy zichligi **deb, jismning bir birlik hajmiga mos kelgan zaryadga miqdor jihatdan teng bo‘lgan fizik kattalikka aytiladi, ya’ni**

$$\rho = \frac{q}{V}$$

bu erda, ***q*** **– jismning** ***V*** **– hajmiga mos kelgan zaryad miqdori.**

Zaryadning sirtiy zichligi **deb, jismning bir birlik sirt yuzasiga mos kelgan zaryadga miqdor jihatdan teng fizik kattalikka aytiladi, yani**

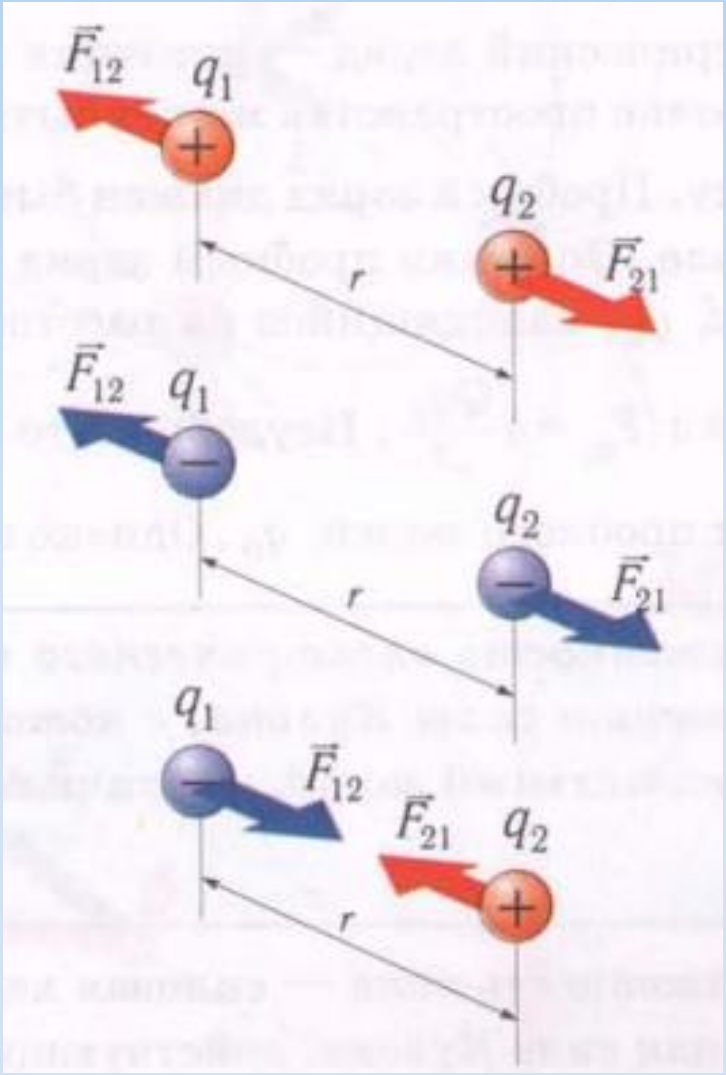
$$\sigma = \frac{q}{S}$$

bu erda, ***q*** **– jismning** ***S*** **yuzasiga mos kelgan zaryad miqdori.**

Zaryadning chiziqli zichligi **deb, jismning birlik uzunligiga mos kelgan zaryadga miqdor jihatdan teng fizik kattalikka aytiladi, ya’ni**

$$\tau = \frac{q}{\lambda}$$

Kulon qonuni



Kulon qonuni

Ikkita qo‘zg‘almas niqtaviy zaryadlar orasidagi o‘zaro ta’sir kuchi zaryadlar miqdorlarining ko‘paytmasiga to‘g‘ri proporsional, ular orasidagi masofaning kvadratiga teskari proporsionaldir va zaryadlarni tutashtiruvchi to‘g‘ri chiziq bo‘ylab yo‘nalgandir

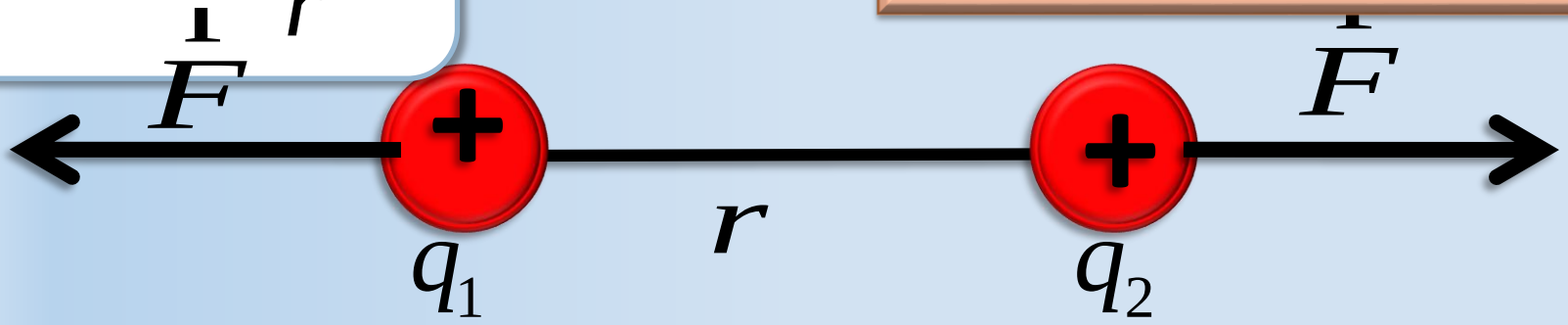
$$F = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2}$$

$$k = \frac{1}{4\pi\varepsilon_0} = 9\times10^9 \frac{N\cdot m^2}{C^2}$$

$$\varepsilon_0 = 8{,}85\times10^{-12}\frac{C^2}{N\cdot m^2}$$

$$F = k\frac{q_1 q_2}{r^2}$$

ELEKTR DOIMIYSI



Izotrop muhitda Kulon qonuni

$$F = \frac{1}{4\pi\varepsilon_0}\frac{q_1 \cdot q_2}{\varepsilon r^2}$$

Vektor ko‘rinishda

$$\vec{F} = \frac{1}{4\pi\varepsilon_0}\frac{q_1 \cdot q_2}{\varepsilon r^3}\vec{r}$$

ε– muhitning dielektrik singdiruvchanligi deb ataladi.

U berilgan muhitning o‘lchamsiz kattaligi bo‘lib, zaryadlar orasidagi o‘zaro ta‘sir kuchi vakuumdagiga qaraganda necha marta kichikligini ifodalaydi

$$\varepsilon = \frac{F_0}{F}$$

Elektr maydonining kuchlanganligi

Elektr maydonining qandaydir nuqtasidagi *E kuchlanganlik* – shu nuqtaga joylashtirilgan sinovchi birlik musbat zaryadga ta’sir etuvchi kuchga miqdor lihatdan teng bo‘lgan *fizik kattalikdir* va u ta’sir etuvchi kuch tomon yo‘nalgandir.

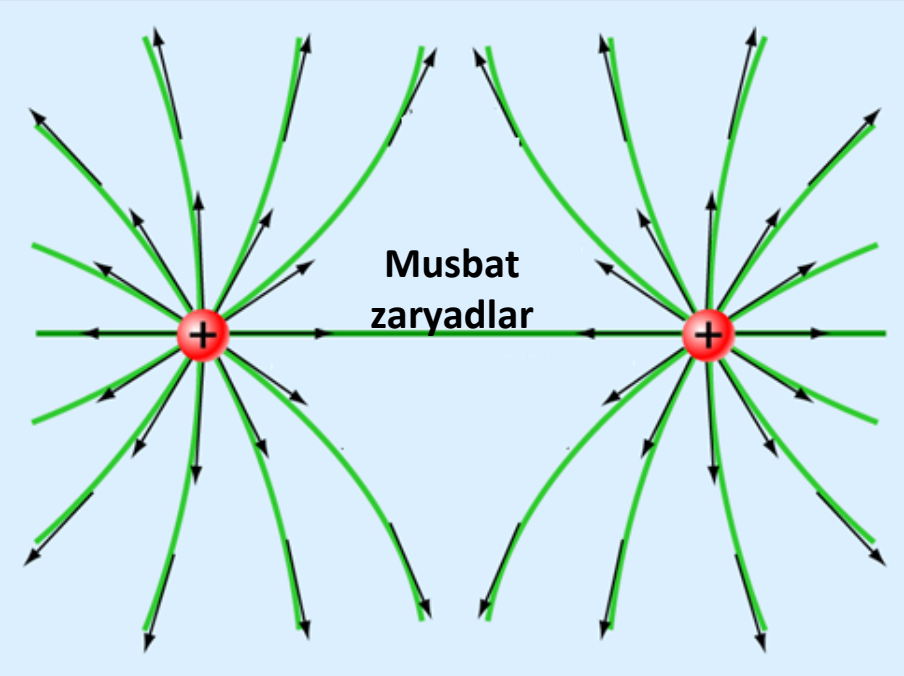
$$\vec{E} = \frac{\vec{F}}{q_0}$$

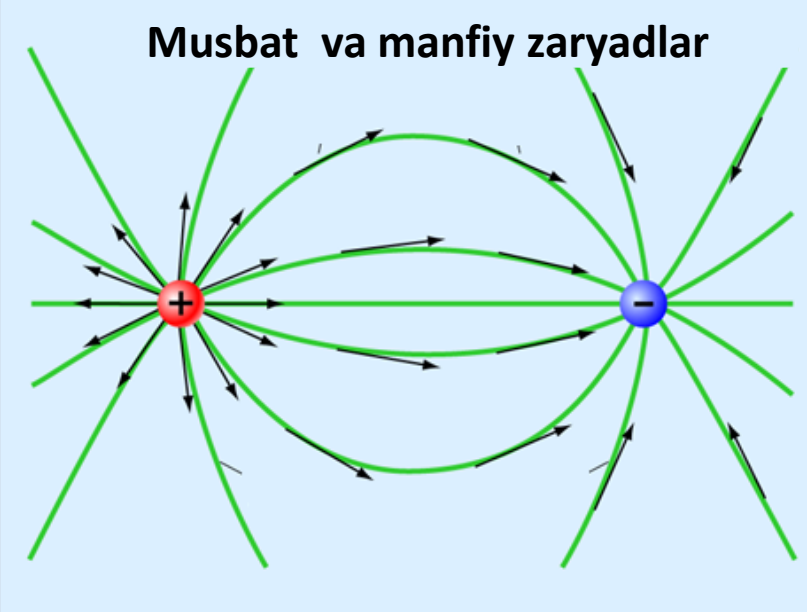
Kuchlanganlik **– maydonning kuch ko‘rsatkichi bo‘lib, *q* nuqtaviy zaryadning *r* masofada xosil qilgan elektr maydonining, ihtiyoriy nuqtaviy zaryadga, ta’sir etuvchi kuchi bilan aniqlanadi.**

$$E = k\frac{q}{r^2} \qquad \vec{E} = k\frac{q\vec{r}}{r^3}$$

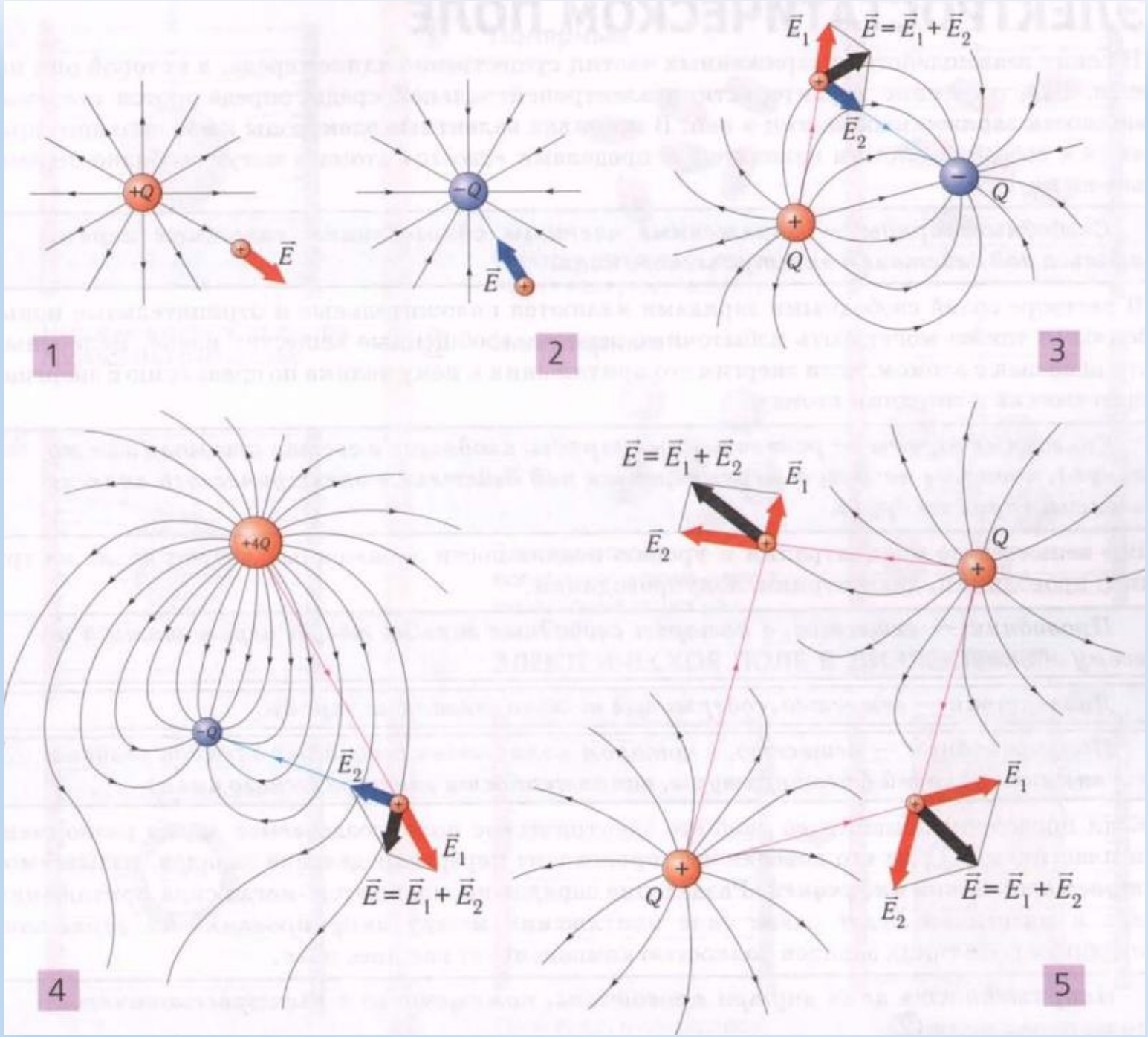
Kuchlanganlik chiziqlari

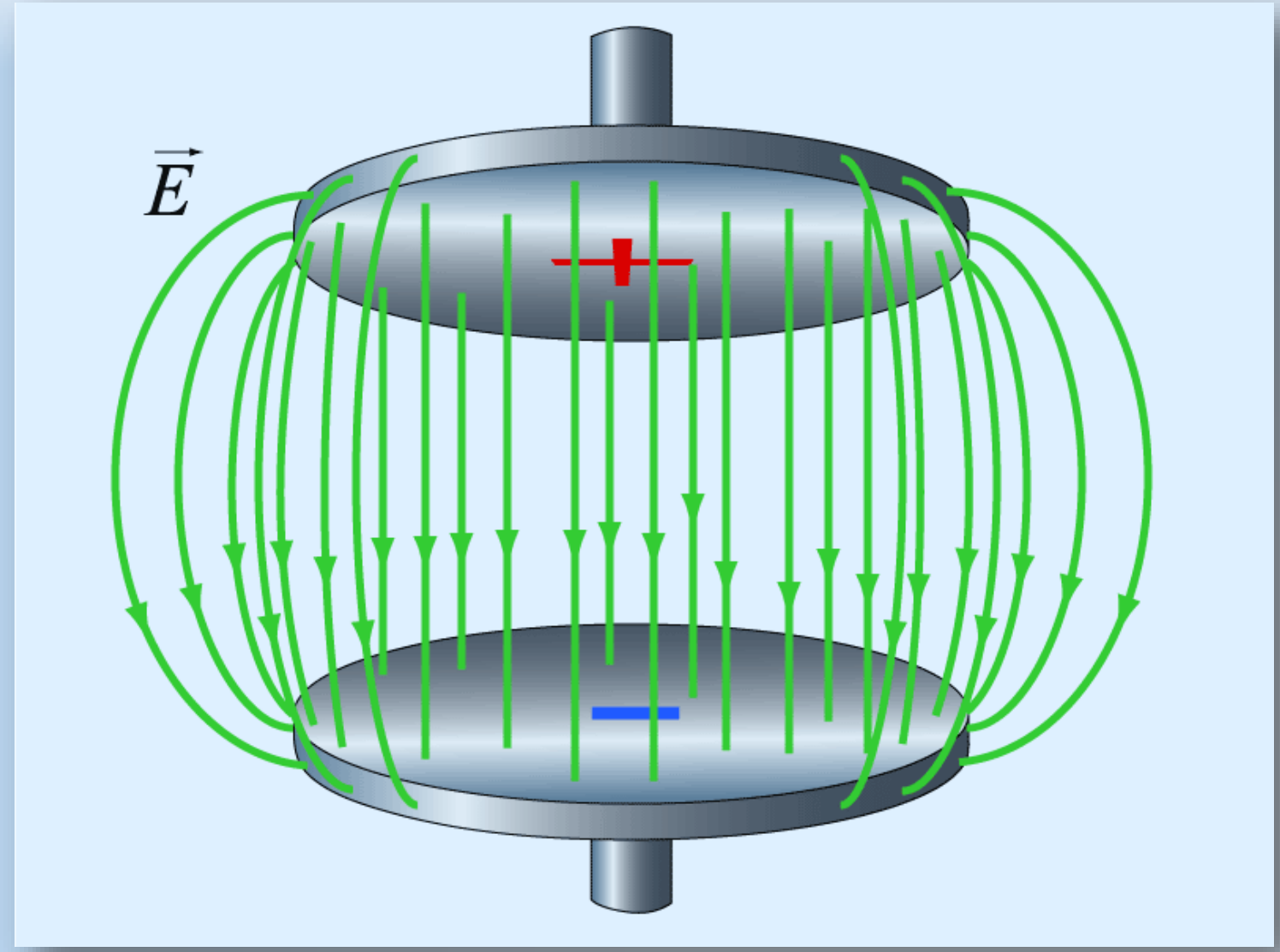
Nuqtaviy zaryadning maydon kuchlanganligi chiziqlari radial chiziqlardan iboratdir. Musbat zaryad uchun kuch chiziqlari yo‘nalishli zaryaddan chiqqan bo‘ladi. Manfiy zaryad uchun esa, kuch chiziqlari yo‘nalishi zaryadga yo‘nalgan bo‘ladi.





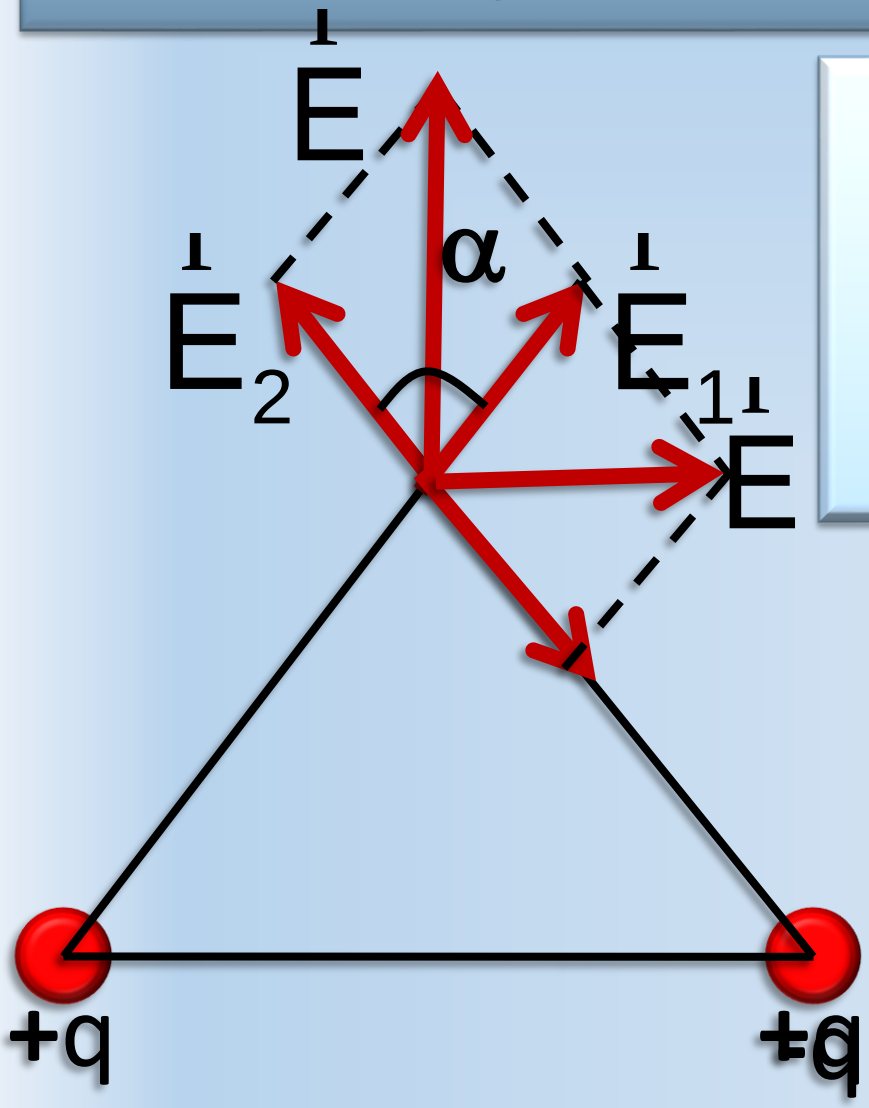
Elektr maydon kuch chiziqlari egri chiziqdan iborat bo‘lsa, kuchlanganlik chiziqlari har bir nuqtaga o‘tkazilgan urinmadan iborat bo‘ladi.


+Q
$\vec{E}$
1
−Q
$\vec{E}$
2
$\vec{E}_1$
$\vec{E} = \vec{E}_1 + \vec{E}_2$
$\vec{E}_2$
Q
Q
3
+4Q
−Q
$\vec{E}_2$
$\vec{E}_1$
$\vec{E} = \vec{E}_1 + \vec{E}_2$
4
$\vec{E} = \vec{E}_1 + \vec{E}_2$
$\vec{E}_1$
$\vec{E}_2$
Q
Q
$\vec{E}_1$
$\vec{E}_2$
$\vec{E} = \vec{E}_1 + \vec{E}_2$
5



Maydonning barcha nuqtalarida kuchlanganlik bir xil bo‘lsa ekektr maydon birjinsli deb ataladi.

Elektr maydonlarining superpozisiya prinsipi.



Zaryadlar tizimining maydonning berilgan nuqtasidagi kuchlanganligi har bir zaryadning alohida kuchlanganliklarining vektor yig‘indisiga tengdir.

$$\vec{E} = \vec{E}_1 + \vec{E}_2 + \ldots + \vec{E}_N = \sum_{i=1}^{N} \vec{E}_i = \frac{1}{4\pi\varepsilon_0\varepsilon} \sum_{i=1}^{N} \frac{q_i \vec{r}_i}{r_i^3}$$

$$E = \sqrt{E_1^2 + E_2^2 - 2E_1E_2\cos\alpha}$$

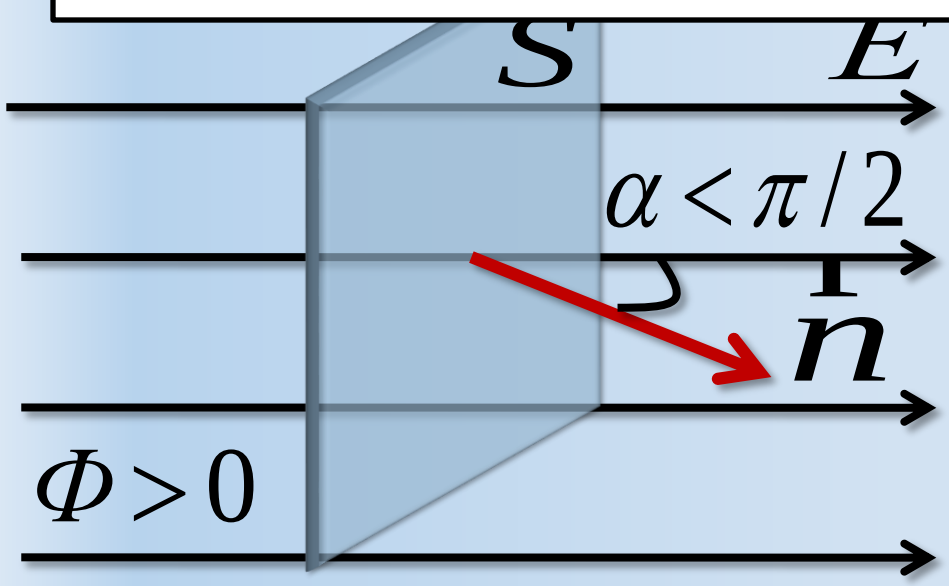
Elektr maydon kuchlanganligi vektorining oqimi.

S **sirtning har xil qismlarida oqimning ishorasi va kattaligi o‘zgaradi:**

1) $\alpha < \pi/2$ **bo‘lganda** $d\Phi_E > 0$,

2) $\alpha > \pi/2$ **bo‘lganda** $d\Phi_E < 0$,

3) $\alpha = \pi/2$ **bo‘lganda** $d\Phi_E = 0$

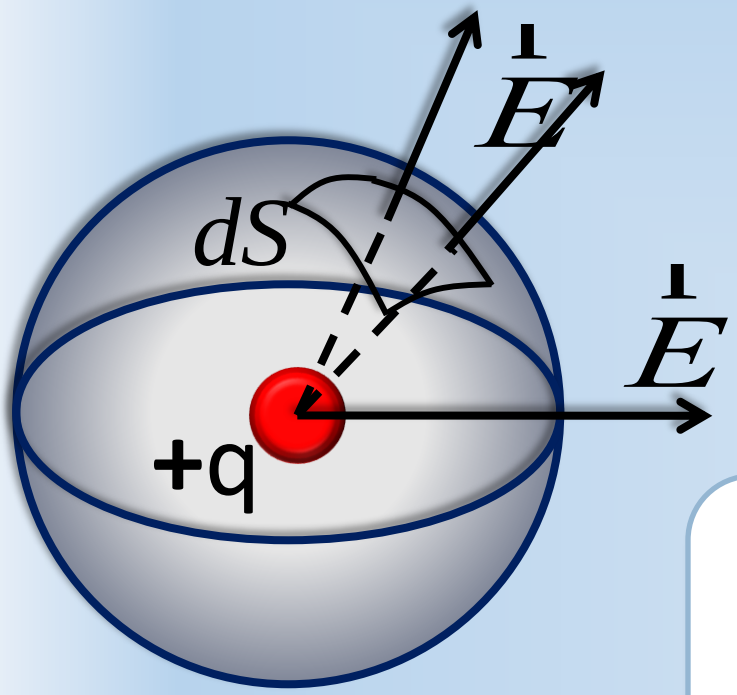


$E_n = E\cos\alpha$ -

E **vektorning** ***dS*** **yuza normali yo‘nalishiga proeksiyasidir**

$$\Phi_E = \oint_S \vec{E}d\vec{S} = \oint_S E_n dS$$

Elektrostatik maydon kuchlanganligi vektori uchun Gauss teoremasi



Markazida *q* nuqtaviy zaryad joylashgan *S* sferik sirt yuzasidan o‘tayotgan *E* вектор оқими quyidagiga teng

bu holda $d\Phi_E = E\,dS,$

chunki sferik sirtning barcha nuqtalarida *E* va *n* yo‘nalishlari bir-biriga mos tushadi.

Nuqteviy zaryadning maydon kuchlanganligi

$$E = \frac{1}{4\pi\varepsilon_0}\frac{q}{R^2}$$

Sfera yuzasi

$$S = 4\pi R^2$$

Kuchlanganlik vektori oqimi

$$\Phi_E = \oint_S \vec{E}\,d\vec{S} = \frac{1}{4\pi\varepsilon_0}\frac{q}{R^2}\oint_S dS = \frac{q}{\varepsilon_0}$$

Agarda elektr maydoni $q_1, q_2, q_3, \ldots$, nuqtaviy zaryadlar tizimi orqali xosil qilinsa superpozisiya prinsipiga asosan, vektorlar oqimi quyidagicha ifodaldnadi:

$$\Phi_E = \oint \vec{E} d\vec{S} = \oint \left(\vec{E}_1 + \vec{E}_2 + \ldots\right) d\vec{S} = \Phi_{E1} + \Phi_{E2} + \ldots = \frac{\sum q_i}{\varepsilon_0}$$

Gauss teoremasi: yopiq sirtdan chiqayotgan *E* elektr maydoni kuchlanganligi vektorining oqimi shu sirt ichidagi zaryadlarning algebraik yig‘indisiga teng.

$$\Phi_E = \frac{\sum q_i}{\varepsilon_0}$$

Divergensiya tushunchasi
Ostrogradskiy – Gauss teoremasi

Quy $\vec{k} = \vec{a}(x, y, z)$

Vek ymiz

$div \varphi(x, y, z)$

$\frac{\partial}{\partial x} \quad \frac{\partial}{\partial y} \quad \frac{\partial}{\partial z}$

Fazoning har bir nuqtasida vektorning divergensiyasini bilgan holda, chekli o‘lchamli istalgan yopiq sirtdan o‘tuvchi shu vektorning oqimini hisoblash mumkin.
Manba’lar quvvati yig‘indisi *V* hajmni o‘rab oluvchi *S* sirt orqali o‘tayotgan vektorlar oqimiga tengdir.

Gamilton operatori - $\nabla = \frac{\partial}{\partial x}\vec{i} + \frac{\partial}{\partial y}\vec{j} + \frac{\partial}{\partial x}\vec{k}$

$$\oint_S \vec{a} d\vec{S} = \int_V div\vec{a} dV$$

Vektor maydon divergensiyasi – skalyar maydondir.

Quyidagi ifoda *Ostrogradskiy – Gauss teoremasi* deb ataladi.

$$div\vec{a} = \lim_{V \to 0} \frac{\Phi_a}{V} = \lim_{V \to 0} \frac{1}{V} \oint_S \vec{a} d\vec{S} = \lim_{V \to 0} \frac{1}{V} \oint_S a_n dS$$

Elektrostatik maydon kuchlanganligi vektori uchun Gauss teoremasining differensial ko‘rinishi

$$\Phi_E = \oint_S \vec{E} d\vec{S} = \oint_S E_n dS = \int_V div\vec{E} dV = \frac{\sum q_i}{\varepsilon_0}$$

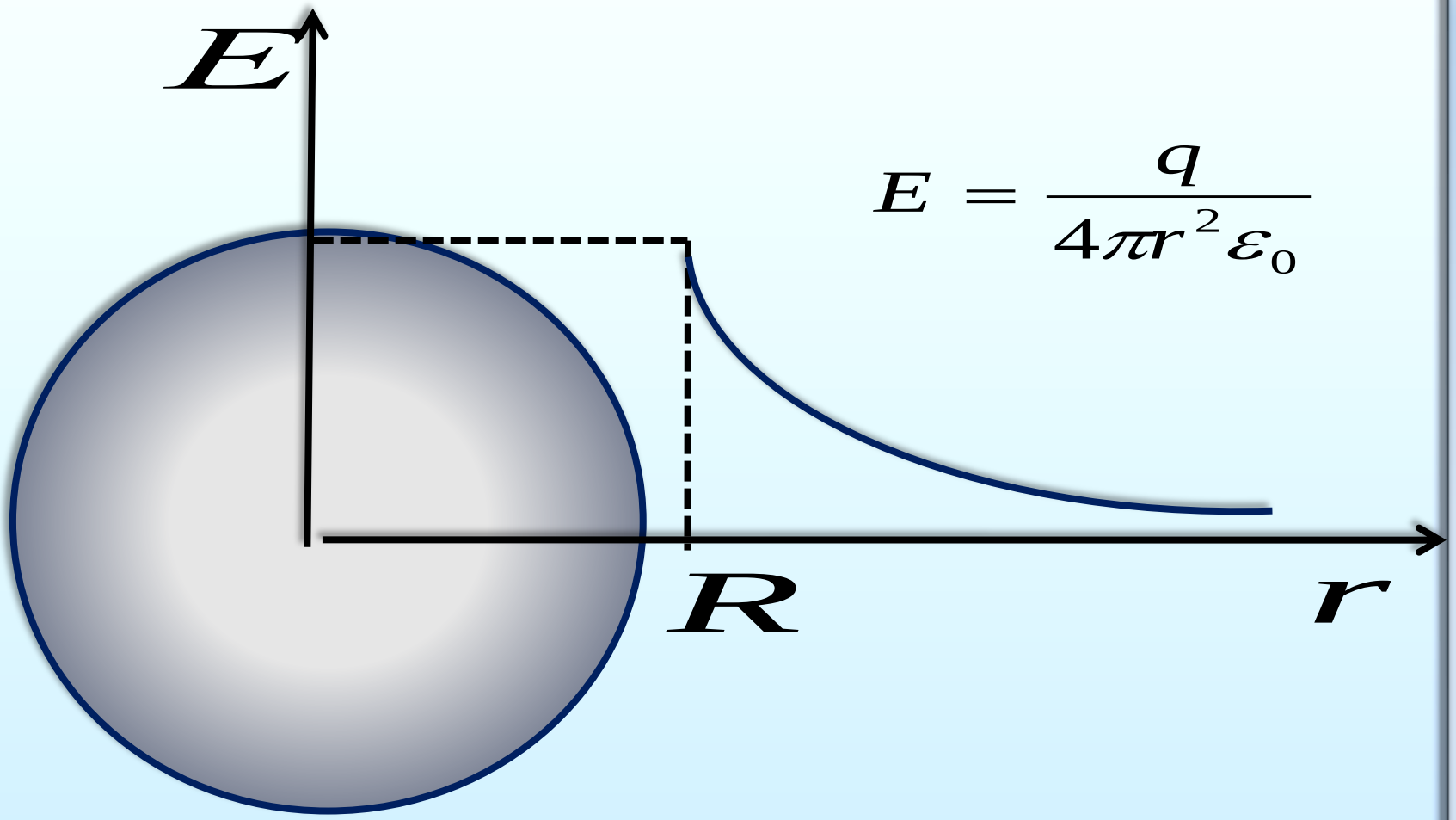
yoki $$\int_V div\vec{E} dV = \frac{\sum q_i}{\varepsilon_0}$$

zaryadlarning hajmiy zichligini hisobga olamiz

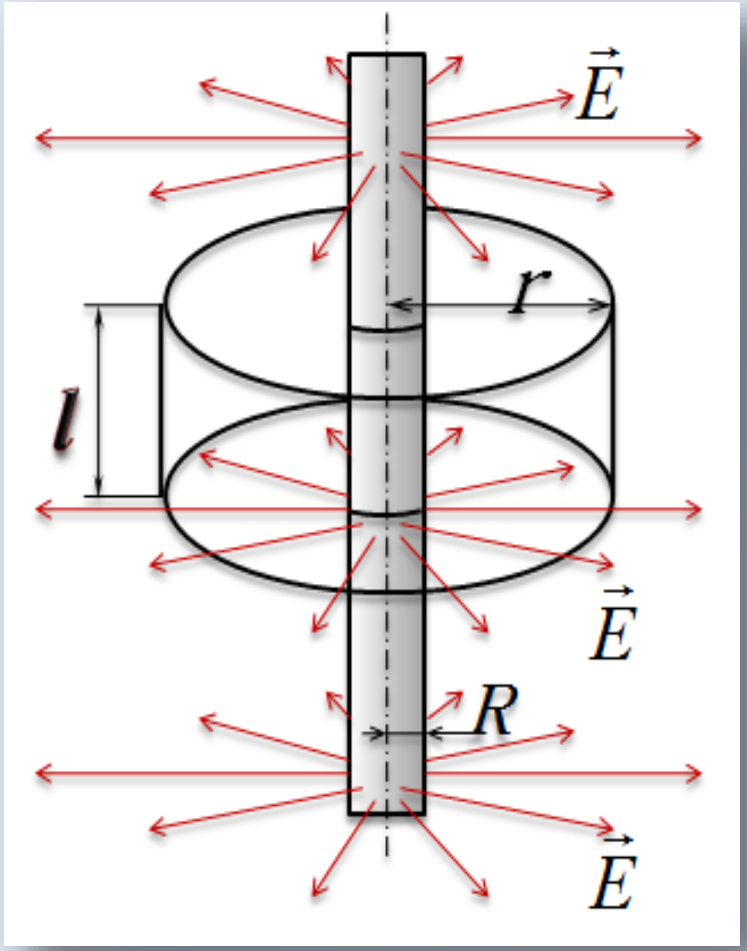
$$\rho = \frac{dq}{dV} \Rightarrow \sum q_i = \int_V \rho dV$$

$$div\vec{E} = \frac{\rho}{\varepsilon_0}$$

$$\nabla\vec{E} = \frac{\rho}{\varepsilon_0}$$



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



Zaryadlangan cheksiz ip (yoki silindr) xosil qilgan elektrostatik maydon kuchlanganligi

Yopiq sirt sifatida radiusi *r* va balandligi *l* bo‘lgan silindrni yasaymiz.

Zaryadlarning chiziqli zichligi $\tau = \frac{dq}{dl}$

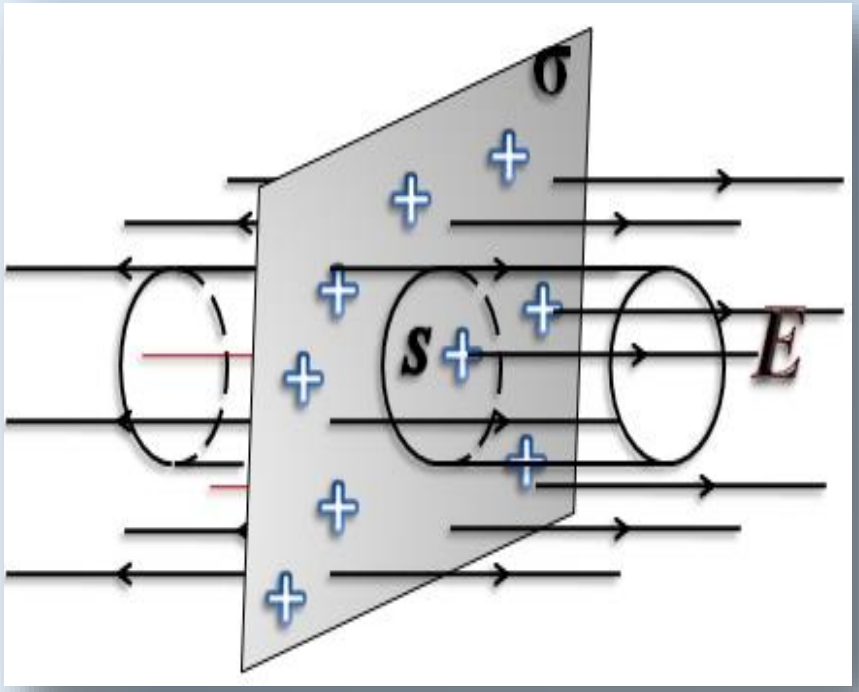
$\vec{E}$

a) agarda $r' > R$ **radiusli silindrning yon sirtidan o‘tgan vektor oqimi Gauss teoremasiga asosan:**

$$EdS = \frac{q}{\varepsilon_0} \Rightarrow E2\pi rl = \frac{q}{\varepsilon_0} \Rightarrow E2\pi rl = \frac{\tau \cdot l}{\varepsilon_0}$$

$$E = \frac{1}{2\pi\varepsilon_0}\frac{\tau}{r}$$

б) agar $r' < R$ ***bo‘lsa*, yopiq sirt ichida zaryad bo‘lmaydi, silindr ichida maydon ham bo‘lmaydi *E = 0*.**



Zaryadlangan cheksiz tekislik xosil qilgan elektrostatik maydon kuchlanganligi

Yopiq sirt sifatida silindrni olamiz. Silindr yon tarafida oqim nolga teng, silindrdan o‘tayotgan to‘la oqim asoslaridan o‘tayotgan oqimlar yig‘indisiga teng.

Zaryadlarning sirtiy zichligi - $\sigma = \frac{dq}{ds}$

$$2ES = \frac{\sigma S}{\varepsilon_0} \Rightarrow$$

$$E = \frac{\sigma}{2\varepsilon_0}$$

FOYDALANILGAN ADABIYOTLAR

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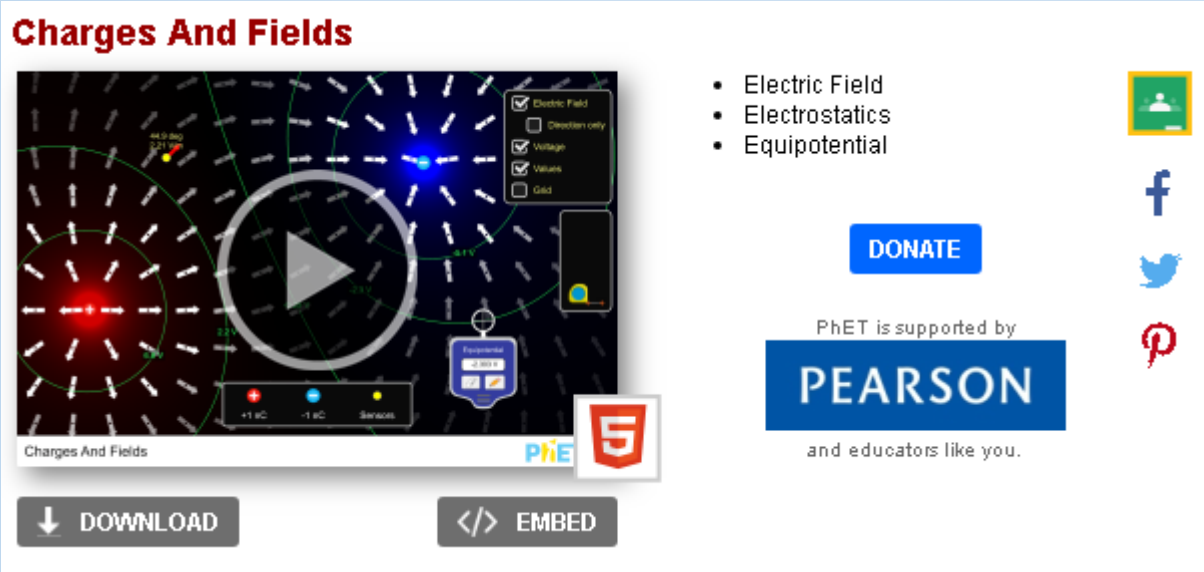
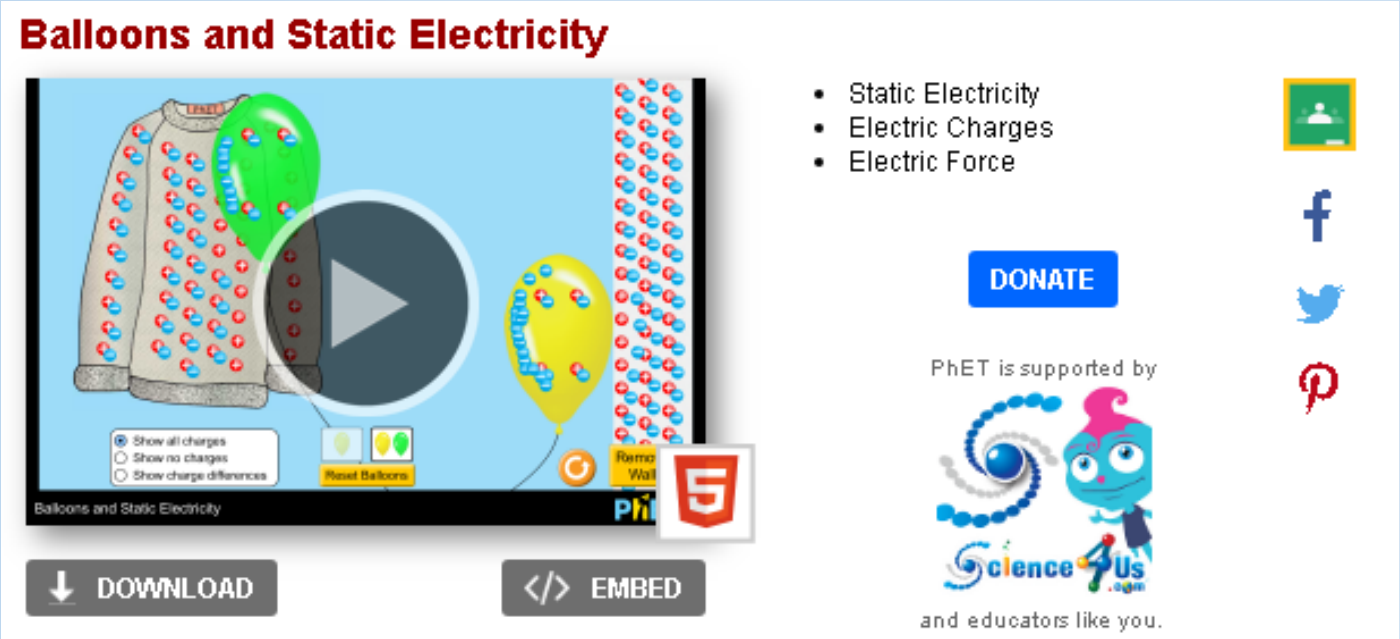
PEDAGOGIK DASTURIY VOSITALAR

- https://phet.colorado.edu/en/simulation/charges-and-fields



PEDAGOGIK DASTURIY VOSITALAR

- https://phet.colorado.edu/en/simulation/balloons-and-static-electricity



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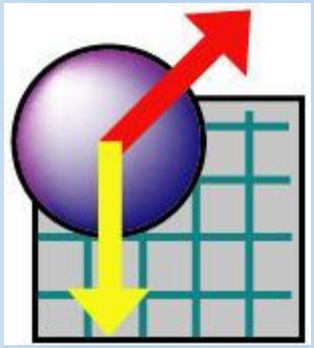
PEDAGOGIK DASTURIY VOSITALAR



- Interactive Physics - Design Simulation Technologies
- Dastur fizikaviy jarayonlarni jonli ko'rinishda tasvirlash imkoniyatini berib, unda tezlanish, ko'chish, kuch va tezlik vektorlarining yo'nalishlarini, tezlikning, tezlanishning, kuchning va boshqa kattaliklarning vaqt bo'yicha o'zgarish grafigini tasvirlash mumkin.

https://www.design-simulation.com/IP/index.php