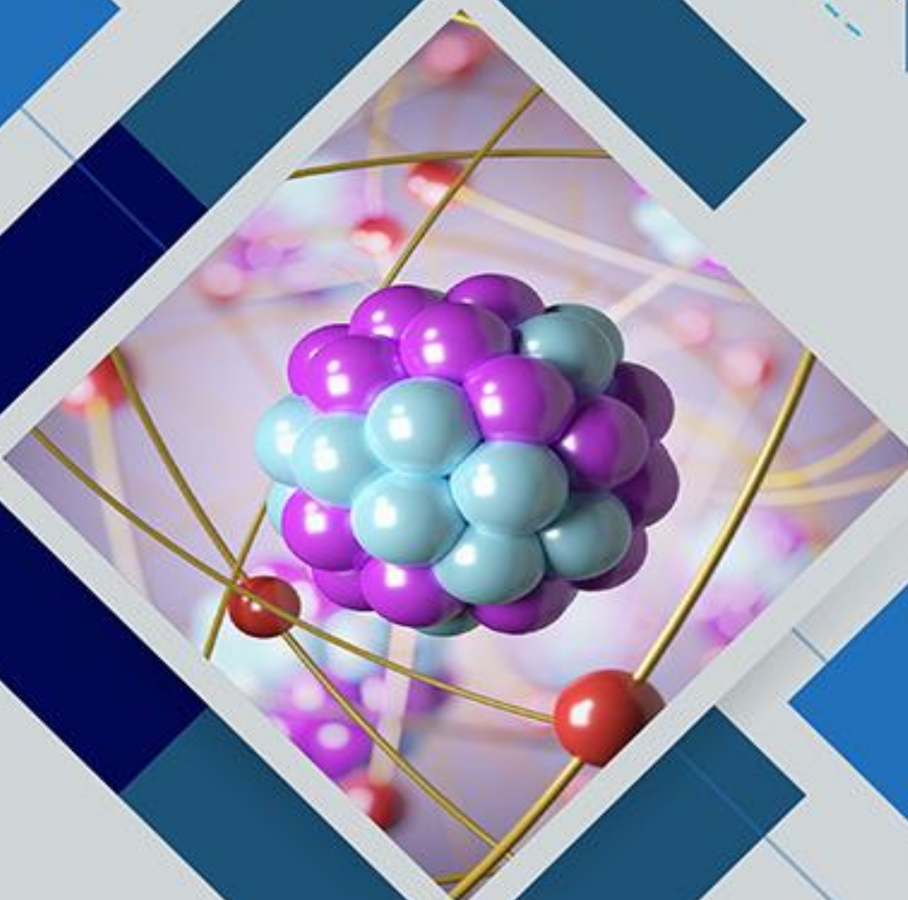
اسألني عن الهندسة



# اسألني عن الفيزياء2

إعداد: عمر الحمري

اسألني عن الهندسة

# بسم الله الرحمن الرحيم

## ❖ المقدمة:

مع كل نظرية فيزيائية ومعادلة تفصيلية تنبثق أفكار لدينا نحن المهندسون لمحاولة الفهم وتخطي العوائق، فمع الفهم الجيد والمحاولة المستمرة وسؤال الخبير تنجلي الطلاسم ونسعد في معرفة الحلول لكل صعب ونرتقي في فهم العلوم الأساسية للهندسة.

فهذه المادة تعتبر لبنة أساسية لاستكمال فهمك صديقي المهندس لمواد المستقبل والانطلاق بهمة لتجاوز الصعب.

فكم من همة أحيت أمة.

ملاحظات ونصائح:

نبذة عن المادة:

## ❖ الهدف من الدوسية:

1)إعطاء طرق سهلة لحل أسئلة مادة الفيزياء.

2)عرض جميع قوانين الكتاب بشكل عام.

3)تسهيل الدراسة على الطالب بحيث تم وضع أسئلة وطرق حلها والإجابات النهائية من أسئلة الكتاب والسنوات السابقة.

4)حل جميع الأسئلة بحيث تضمن أعلى النتائج بحول الله.

## ❖ ملاحظة:

في كل نهاية وحدة يوجد الحل النهائي **(final answer)** لأسئلة كل وحدة.

## ❖ نصائح طالب:

*المادة تعتمد بشكل كبير على الفهم قبل الحفظ وعلى كثرة حل الأسئلة فبقدر ما تنجز بحل الأسئلة بقدر ما يتم استيعاب المادة.

*يجب فهم المادة فهماً دقيقا لأن طبيعة الأسئلة لا تأتي بشكل مباشر وإنما تعتمد على فهم الطالب.

## ❖ وفي النهاية نتمنى التوفيق والسداد لجميع الطلاب وأن نكون عند حسن ظنكم.

{Done by: Omar Mohammad}

# CHAPTER 21:

## ELECTRIC CHARGE & ELECTRIC FIELD

# Chapter 21: Electric Charge & Electric Field

تتكون المادة من ذرات وتتكون الذرة من:

1)البروتونات (the positively charged proton).
2)الإلكترونات (the negatively charged electron).
3)النيوترونات (uncharged).

الذرة المتعادلة يكون فيها عدد الالكترونات مساوي لعدد البروتونات.

إذا فقدت المادة إلكترونات فإنها تصبح موجبة الشحنة لأنها فقدت شحنات سالبة (the substance that lost electrons).
إذا اكتسبت المادة إلكترونات فإنها تصبح سالبة الشحنة لأنها اكتسبت شحنات سالبة (the substance that gained electrons).
لذلك فإن شحنة أي جسم يجب أن تكون من مضاعفات شحنة الإلكترون وهذا ما يسمى بمبدأ تكمية الشحنة.

the principle of quantization of the charge (مبدأ تكمية الشحنة):

$$q = ne$$

Where:
$q$:the charge on body.
$n$: number of (lost or gained) electrons (عدد الإلكترونات المفقودة أو المكتسبة)
$e$: the negatively charged electron( $e = 1.6 * 10^{-19}$ )

P=$10^{-12}$
n=$10^{-9}$
$\mu$=$10^{-6}$
m=$10^{-3}$
k=$10^{3}$
M=$10^{6}$
G=$10^{9}$

Ex: if an object lost (3*$10^{10}$ e), what is its charge?
Solution:
$q = ne \Rightarrow q = 3 * 10^{10} * 1.6 * 10^{-19} \Rightarrow q = 4.8 * 10^{-9}\ C$
$q = 4.8\ nC$, positive because it lost electrons

## coulomb's Law:

تنشأ بين الأجسام المشحونة قوة كهربائية تكون تنافرا أو تجاذبا:
تنشأ قوة تجاذب بين الشحنات المختلفة (A positive and a negative charges attract each other).
تنشأ قوة تنافر بين الشحنات المتشابهة (Two positive and two negative charges repel each other).

تمكن العالم كولوم من تحديد العوامل التي يعتمد عليها مقدار القوة الكهربائية المتبادلة بين شحنتين نقطيتين:
1)مقدار القوة الكهربائية ($F$) يتناسب طرديا مع مقدار كل من الشحنتين ($|q_1\ q_2|$).
2)تتناسب عكسيا مع مربع المسافة بينهما ($r^2$).
3)تعتمد على طبيعة الوسط الذي توجد في الشحنات.

"The magnitude of the electric force between two-point charges is directly proportional (طرديا)to the product of the charges and inversely(عكسيا) proportional to the square of the distance between them".

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

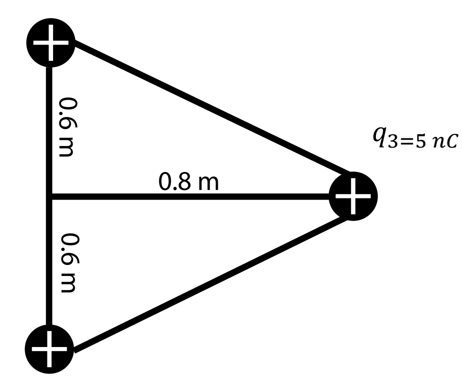
Where:
$F$: Magnitude of electric force between two point charges
$k$: coulombs constant ($k = \frac{1}{4\pi\epsilon_\circ} = 9 * 10^9$)
r: Distance between the two charges.
$(q_1)(q_2)$: Values of the two charges
$\epsilon_\circ$: Electric constant ($\epsilon_\circ = 8.85 * 10^{-12}$).

**عندما تكون لديك الرغبة المشتعلة للنجاح فلن يستطيع أحد إيقافك**

Ex1: Two-point charges $q_1$=20 nC, $q_2$=50 nC and the distance between them = 3 cm, find:
a) what is the magnitude and direction of electric force from $q_1$ exerts $q_2$.
b) the electric force from $q_2$ exerts on $q_1$.
Solution:

$a)\ F = k\frac{q_1\, q_2}{r^2} \Rightarrow\ F = 9*10^9\,\frac{20*10^{-9}*50*10^{-9}}{(3*10^{-2})^2}$
$F = 1*10^{-2}\ N \Rightarrow F = 10\ mN$ (repel).
b) the same result of (a) $F = 10\ mN$ (repel), لأن الضرب عملية تبادلية.

Ex2: given figure below, what is the total force on $q_3$ ?
Solution:




$r_1 = \sqrt{(0.6)^2 + (0.8)^2} \Rightarrow r_1 = 1m$

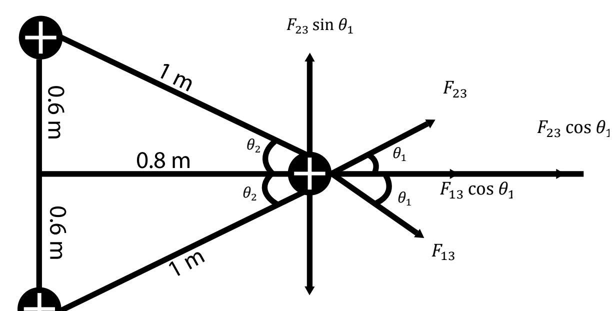
$r_1$=$r_2$ from Pythagoras ($c^2 = a^2 + b^2$)

$\theta_1$ ونفس $F_{13} = F_{23}$ تساوي صفر لأن

$F_{13} = k\frac{q_1\, q_3}{{r_1}^2} \Rightarrow F_{13} =\ 9*10^9\ \frac{10*10^{-9}\ *5*\ 10^{-9}}{(1)^2}$
$F_{13} = 450\ nN$

$F_{23} = k\frac{q_1\, q_3}{{r_2}^2} \Rightarrow F_{23} =\ 9*10^9\ \frac{10*10^{-9}\ *5*\ 10^{-9}}{(1)^2}$
$F_{23} = 450\ nN$

*The total Force (نحتاج إلى تحليل المتجهات كما في الشكل المجاور)




بالتبادل $\theta_1 = \theta_2$

$F_y = F_{23}\sin\theta_1 = F_{13}\sin\theta_1 = 0$

$F_x = F_{13}\cos\theta_1 + F_{23}\cos\theta_1$

$F_x = 450*10^{-9}$ *0.8 + $450*10^{-9}$ * 0.8

$F_x = 2*450*10^{-9}$ *0.8

$F_x = 7.2*10^{-7}$

$F_x = 0.72\mu N\ \left(\hat{i}\right)$

$\sin\theta_1 = \sin\theta_2 = \frac{0.6}{1.0} = 0.6$

$\cos\theta_1 = \cos\theta_2 = \frac{0.8}{1.0} = 0.8$

## Electric Field (المجال الكهربائي): $E$

يعد المجال الكهربائي $(\boldsymbol{E})$ خاصية للحيز المحيط بالشحنة الكهربائية $(q)$ يظهر تأثيره على شكل قوة كهربائي $(F)$ تؤثر في شحنة أخرى توضع في هذا الحيز، لذلك تصنف القوة الكهربائية بأنها قوة مجال كهربائي، وتستخدم في الكشف عن المجال الكهربائي شحنة نقطية صغيرة موجبة تسمى شحنة اختبار $(q_0)$ فعند وضعها عند نقطة ضمن المجال الكهربائي فإنها تتأثر بقوة كهربائية ويكون المجال الكهربائي $(\boldsymbol{E})$ عند النقطة مساويا لمقدار القوة الكهربائية $(F)$ مقسومة على شحنة الاختبار $(q_0)$.

فالمجال الكهربائي عند نقطة يساوي:

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

Where:

$F$: Electric force on a test charge $q_0$ due to other charges

$E$: Electric field

$q_0$: Value of test charge

unit of [E]: N/C.

Electric field due to point charge:

يمكن حساب المجال الكهربائي عند نقطة $(E = \frac{F}{q_0})$ ولكن إذا كان مصدر المجال الكهربائي شحنة نقطية فيمكن حساب المجال الكهربائي عند أي نقطة تبعد عنها من خلال:

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

$$F = k\frac{|q\, q_0|}{r^2} \Rightarrow E * q_0 = k\frac{|q\, q_0|}{r^2} = E = k\frac{|q|}{r^2}$$

$$\vec{E} = k\frac{|q|}{r^2}\hat{r}$$

Where:

$E$: Electric field due to a point charge

$\hat{r}$: Unit vector from point charge toward where field is measured.

$\hat{r} = \frac{\vec{r}}{r}$ (تستخدم في حال اذا كانت المسافة بين الشحنة والنقطة في بعدين مثال اذا كانت )

$$\hat{r} = ((-0.73\ )\hat{i} + (0.390\ \hat{k}))m$$

$$\hat{r} = \frac{\vec{r}}{r} = \frac{(-0.73\ )\hat{i} + (0.390\ \hat{k})}{\sqrt{(-0.73\ )^2 + (0.390\ )^2}}$$

Electric field is a vector quantity that means it has magnitude and direction.

(المجال الكهربائي كمية متجهة له قيمة واتجاه).

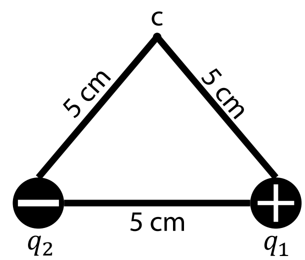
Direction of (E): ⊕ $q_0 \rightarrow \vec{E}$

⊖ $\vec{E} \leftarrow q_0$

$q_0$ always positive charge and it is very small.

{Done by: Omar Mohammad}

Ex1: Two-point charges $q_1$=5 $\mu$C, $q_2$=-5 $\mu$C distance between them 5 cm in figure shown, find $\vec{E}$ at point c?




Solution:

$E_1 = k\frac{q_1}{r^2} \Rightarrow E_1 = 9 * 10^9 \frac{5 * 10^{-6}}{(5 * 10^{-2})^2}$

$E_1 = \frac{9}{5} * 10^7$ N/C $\Rightarrow E_1 = 1.8 * 10^7$ N/C.

$E_2 = k\frac{q_1}{r^2} \Rightarrow E_2 = 9 * 10^9 \frac{5 * 10^{-6}}{(5 * 10^{-2})^2}$

$E_2 = \frac{9}{5} * 10^7$ N/C $\Rightarrow E_2 = 1.8 * 10^7\ N/C$ .

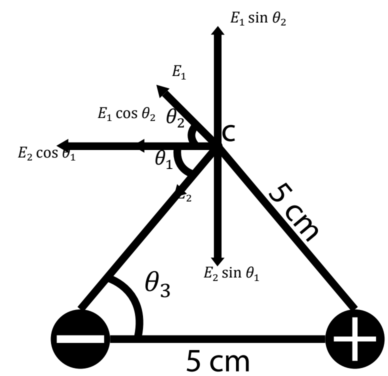
*السالب لا يعوض عند إيجاد المجال

*الإشارة لتحديد الإتجاه فقط

* من الرسم نجد قيمة $\theta_1$ تساوي 60 درجة لأن المثلث متساوي الأضلاع.

* $\theta_1 = \theta_2 = \theta_3$ بالتناظر .

لإيجاد $E_{net}$ :




$E_x = E_1 \cos\theta_2 + E_2 \cos\theta_1 \Rightarrow E_x = 1.8 * 10^7 \cos 60^0 + 1.8 * 10^7 \cos 60^0$

$E_x = 1.8 * 10^7\ N/C \left(-\hat{i}\right)$

$E_y = E_1 \sin\theta_2 - E_2 \sin\theta_1 = 0$

تساوي صفر لأن $E_1 = E_2$ و $\theta_1 = \theta_2$

المجال الكهربائي الناشئ عن شحنة نقطية غير منتظم أي انه غير ثابتة في المقدار والاتجاه وكلما ابتعدنا عن المصدر يقل المجال الكهربائي بسبب زيادة المسافة.

## Electric field lines (خطوط المجال الكهربائي):

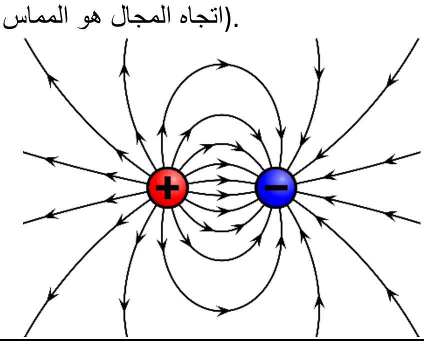
Properties of electric field lines:

1) electric field lines point away from positive charge ($q^+$) and toward to negative charge ($q^-$).
(الخطوط تخرج من الشحنة الموجبة وتدخل في الشحنة السالبة).

2) electric field lines are close together where the field is strong, farther apart where it is weaker.
(الخطوط تكون متقاربة عند المجال الأقوى ومتباعدة عن المجال الأضعف).

3) direction of electric field is tangent of lines in any point (اتجاه المجال هو المماس لأي نقطة في الخطوط).

4) electric field lines do not intersect (خطوط المجال لا تتقاطع).



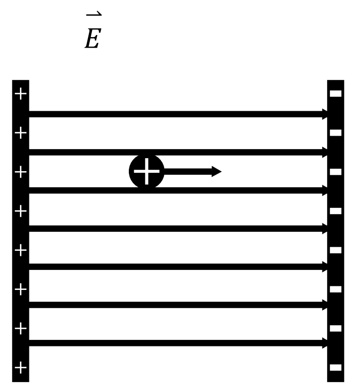
**Uniform Electric Field (المجال الكهربائي المنتظم):**

**عند شحن صفحتين موصلتين متوازيتين إحداهما بشحنة سالبة والأخرى موجبة فإن الشحنات تتوزع على سطحيهما بانتظام، وينشأ مجال كهربائي منتظم ثابت مقدارا واتجاها عند النقاط جميعها في الحيز بين الصفحتين بعيدا عن الأطراف.**

**فإذا كان مقدار الشحنة الكهربائي الموزعة على إحدى الصفيحتين (q) ومساحة الصفيحة (A) فإن كمية الشحنة لكل وحدة مساحة تسمى الكثافة السطحية للشحنات ($\sigma$) حيث ($\sigma = \frac{q}{A}$) وتقاس بوحدة ($\frac{C}{m^2}$).**

**اذا كانت الكثافة السطحية لشحنة على الصفيحتين متساوية وكان الوسط بين الصفيحتين هواء أو فراغ فإن المجال الكهربائي.**

$$E = \frac{\sigma}{\epsilon_0}$$




Where:

$\sigma$: charge density

Ex1: A proton is placed in a uniform $E$ = 5* $10^3 \frac{N}{C}$ ($q_{proton} = 1.6 * 10^{-19}\ C$, $mass = 1.672 * 10^{-27}\ Kg$), find:
a) magnitude of Force (F) on the proton.
b) proton acceleration (عند إهمال الوزن).
C) speed after $1\mu s$.

Solution:

a) $F = E\ q_0 \Rightarrow F = 5 * 10^3 * 1.6 * 10^{-19} \Rightarrow F = 8 * 10^{-16}\ N$

b) $\sum F = ma$ , from Newton's law $\Rightarrow 8 * 10^{-16}$ = $1.672 * 10^{-27} * a \Rightarrow a = \frac{8*10^{-16}}{1.672*10^{-27}}$

$a = 4.78 * 10^{11}\ m/s^2$

c) $v_2 = v_1 + at$, $v_1$=0 (is placed) $\Rightarrow v_2 = 0 + 4.78 * 10^{11} * 1 * 10^{-6} \Rightarrow v_2$ = 4.78* $10^5$m/s

عندما يوضع جسيم مشحون كتلته ($m$) في مجال كهربائي منتظم فإنه يتأثر بقوة كهربائية فإذا تحرك الجسيم تحت تأثير القوة الكهربائية فإنه سيكتسب تسارعا ($a$) ثابتا مقدارا واتجاها.

$F = am \quad , \quad F = E * q$

$F = am = E * q$

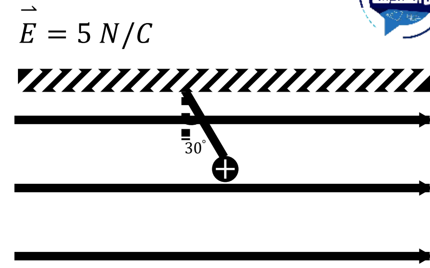
$a = \frac{E * q}{m}$

ويكون اتجاه التسارع باتجاه القوة الكهربائية، فإن حركة الجسيم يمكن وصفها باستخدام معادلات الحركة بتسارع ثابت:

$$v_2 = v_1 + at$$

$$v_2{}^2 = v_1{}^2 + 2a\Delta L$$

$$\Delta L = t * v_1 + 0.5at^2$$

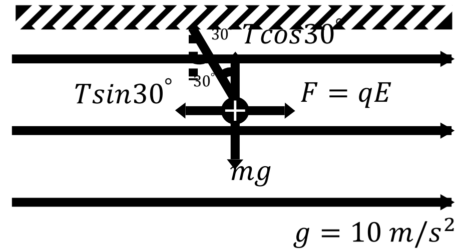



Ex2: in the figure shown, find (q is equilibrium)
a) Tension of rope.
b) q if its mass = 10 g.

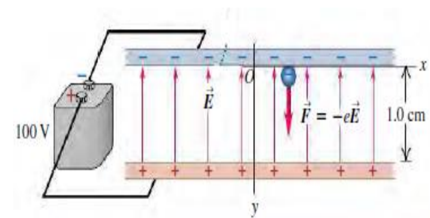
Solution:
a) because q is equilibrium then, $Tcos30 = mg$ & $Tsin30 = qE$

$T = \frac{mg}{\cos 30} \Rightarrow T = \frac{10*10^{-3}*10}{\cos 30} \Rightarrow T = 0.113\ N$

b) $Tsin30 = qE \Rightarrow q = \frac{Tsin30}{E} \Rightarrow q = \frac{0.113*0.5}{5} \Rightarrow q = 11.3\ mC$




Example: When the terminals of a battery are connected to two parallel conducting plates with a small gap between them, the resulting charges on the plates produce a nearly uniform electric field $\vec{E}$ between the plates. If the plates are 1.0 $cm$ apart and are connected to a 100 − $volt$ battery as shown, the field is vertically upward and has magnitude E = 1.00 $*10^4$ N/C.
(a) If an electron ($charge\ -e = -1.60 * 10^{-9}\ C, mass\ m = 9.11 * 10^{-31}\ kg$) is released from rest at the upper plate, what is its acceleration?
(b) What speed and kinetic energy (k) does it acquire while traveling 1.0 cm to the lower plate?
(c) How long does it take to travel this distance?




Solution:
a)
$F_y = a_y m = E * q$
$a_y * 9.11 * 10^{-31} = 1.00 * 10^4 * -1.60 * 10^{-9}$
$a_y = -1.71 * 10^{15}$

b)
from rest: $v_{y1} = 0$
$L_0 = 0, so\ at\ L_1 = -1.0\ cm = -1.0 * 10 - 2\ m$

$v_{y2}{}^2 = v_{y1}{}^2 + 2a\Delta L$

$v_{y2}{}^2 = 0 + 2 * (-1.71 * 10^{15}) * -1 * 10^{-2}$

$v_{y2} = 5.9 * 10^6$ (m/s)

$k = 0.5 * m * v^2 = 0.5 * 9.11 * 10^{-31} * (5.9 * 10^6)^2 = 1.6 * 10^{-17} J$

c) t $= \frac{v_2 - v_1}{a} = 3.4 * 10^{-9} s$

احرص على استثمار عمرك بالخير، واحذر من الفراغ أو الشر، فالحياة
فرصة أتتك ولن تتكرر

{Done by: Omar Mohammad}

**Electric field absence point (نقطة انعدام المجال):**

⊕ ⊕ or ⊖ ⊖

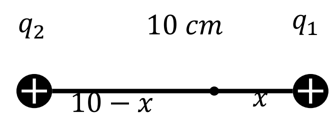
- the point is between them and closer to the smaller charge (بينهما وأقرب إلى الشحنة الأصغر).

⊕ ⊖

- the point is outside them and closer to the smaller charge (خارجهما وأقرب إلى الشحنة الأصغر).

Ex: Two charges $q_1$=5 $n$C, $q_2$=10 $n$C, distance between them 10 $cm$, find the absence point.

Solution:




$$E_1 = E_2 \Rightarrow \frac{k\,q_1}{r_1^2} = \frac{k\,q_2}{r_2^2} \Rightarrow q_1\,r_2^2 = q_2\,r_1^2, r_1 = x \;\&\; r_2 = 10 - x$$

$5 * 10^{-9} * (10-x)^2 = 10 * 10^{-9} * (x)^2$ … take the root after simplification.

$$\sqrt{(10-x)^2} = \sqrt{2x^2} \Rightarrow 10 - x = \sqrt{2}\,x \Rightarrow \sqrt{2}\,x + x = 10$$

$$x = \frac{10}{1+\sqrt{2}}\,cm \Rightarrow x = 4.14\,cm$$

**Electric field for charge distribution (المجال الكهربائي لتوزيع من الشحنات):**

**تتوزع الشحنات في بعد مثال على طول خط مستقيم أو في بعدين مثال على مساحة دائرة أو في ثلاث أبعاد مثال حجم كرة**

| Along line | Over surface | Through a volume |
|---|---|---|
| $\lambda$: *line charge density* | $\sigma$: *surface charge density* | $\rho$: *volume charge density* |
| $\lambda = Q/l$ | $\sigma = Q/A$ | $\rho = Q/V$ |
| $q = \lambda l \Rightarrow dq = \lambda dl$ | $q = \sigma A \Rightarrow dq = \sigma dA$ | $q = \rho V \Rightarrow dq = \rho dV$ |

$$E = \int k\frac{dq}{r^2}\hat{r}$$

$\int \boldsymbol{dl} = L$(الطول)  $\int \boldsymbol{dS} = A$(المساحة)  $\int \boldsymbol{dV} = V$(الحجم)

**Types:**

1)rod:

a.


$E_b = k\frac{\lambda l}{a(a+l)}$

توزيع الشحنات على خط طوله $(L)$ يبعد مسافة عن النقطة (b) مقدارها (a) فإن المجال عند النقطة (b) يساوي:

$dq = \lambda dl$

$E = \int k\frac{dq}{r^2} = \int k\frac{\lambda dl}{r^2}$

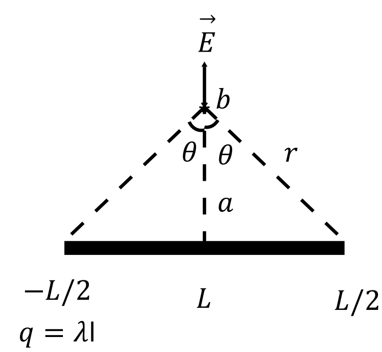
حدود التكامل الحد الأول من بداية توزيع الشحنات الى النقطة المراد القياس عندها $(L + a)$ والحد الثاني من نهاية تويع الشحنات الى النقطة المراد القياس عندها $(a)$.

$$E = k\lambda\int_a^{L+a}\frac{1}{l^2}dl = -k\lambda * (\frac{1}{L+a} - \frac{1}{a})$$

$$E_b = k\frac{\lambda l}{a(a+l)}$$

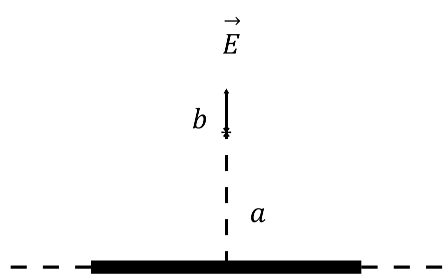
b. finite rod:

$E_b = \frac{2k\lambda\sin\theta}{a}$ $or$ $E_b = \frac{k\lambda l}{a\sqrt{a^2+l^2/4}}$




c. infinite rod:

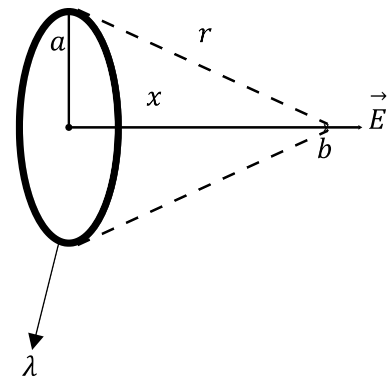
$E_b = \frac{2k\lambda}{a}$



2) ring:

$$E_b = \frac{kQx}{(x^2 + a^2)^{3/2}}$$

$$E_c = 0$$




$Q = \lambda l, l = 2\pi a$

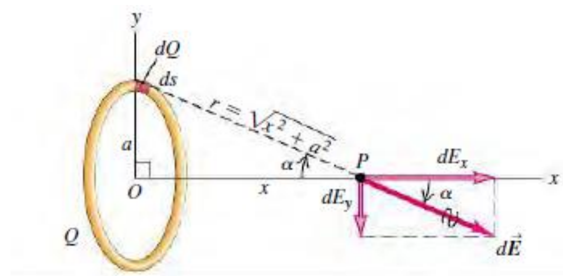
$Q = \lambda(2\pi a)$

$a: raduis$

$$\vec{E} = \int k \frac{dq}{r^2}\hat{r} = \int k \frac{\lambda dl}{r^2}\hat{r}$$

$$r = \sqrt{x^2 + a^2}$$

$$\int \boldsymbol{dl} = L(\text{المحيط}) = 2\pi R$$




$$E = k\frac{\lambda 2\pi R}{(x^2 + a^2)}$$

$$dE_x = dE * \cos\alpha$$

$$\cos\alpha = \frac{\mathrm{x}}{r} = \frac{\mathrm{x}}{\sqrt{x^2 + a^2}}$$

$$E_x = k\frac{\lambda 2\pi R}{(x^2 + a^2)} * \frac{\mathrm{x}}{\sqrt{x^2 + a^2}} = \frac{\lambda 2\pi R x}{(x^2 + a^2)^{3/2}}$$

$$\vec{E} = \frac{kQx}{(x^2 + a^2)^{3/2}}\hat{i}$$

3) disk:

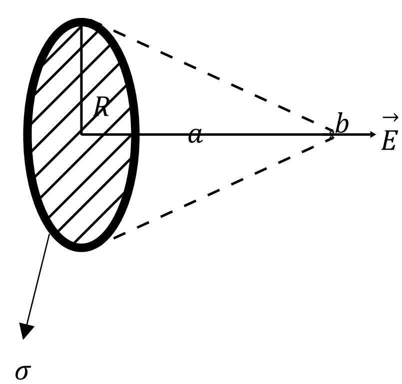
$$E_b = 2\pi k\sigma\left[1 - \frac{a}{\sqrt{R^2 + a^2}}\right]$$

$Note: \pi\ is\ in\ rad = 3.14\ or\ 22/7$

$Q = \sigma A, A = \pi R^2$

$Q = \sigma(\pi R^2)$

$R: raduis$



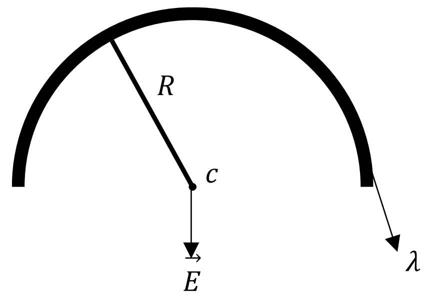
4) semi-circle:

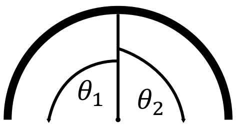
$$E_c = \frac{k\lambda}{R}[\sin\theta_1 + \sin\theta_2]$$

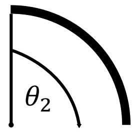
$$Q = \lambda l, l = \pi R$$

$$Q = \lambda(\pi R)$$

$R: raduis$




$\theta_1 = 90°$

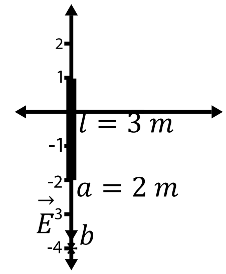
$\theta_2 = 90°$

$\theta_1 = 0°$

$\theta_2 = 90°$

Ex1: A uniform linear charge of 5 $nC/m$ distributed a long $y=-2m\ \ to\ y=1m$, find $\vec{E}$ at $y=-4m$ ?

Solution:

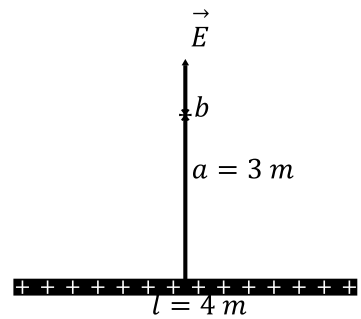



$E_b = k\frac{\lambda l}{a(a+l)}$, $l = 3\ m\ from\ figure\ \Rightarrow E_b = 9*10^9\frac{5*10^{-9}*3}{2*(2+3)}$

$E_b = 13.5\ N/C\ \left(-\hat{J}\right)$

Ex2: rod its length 4 $m$ is uniformly charged with 40 $nC$, find $\vec{E}$ At point it 3 $m$ away from center of rod(above)?

Solution:

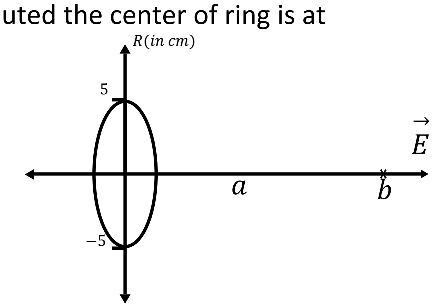



$E_b = \frac{k\lambda l}{a\sqrt{a^2+l^2/4}}$ , $Q=\lambda l \Rightarrow E_b = \frac{9*10^9*40*10^{-9}}{3*\sqrt{9^2+4^2/4}}$

$E_b = 33.28\ N/C\ \left(\hat{J}\right)$

$Note: if\ charge\ be\ negative\ the\ direction\ will\ be\ \left(-\hat{J}\right)$

Ex3: A ring with radius 5 $cm$ has total charge $q=0.25\ nC$ uniformly distributed the center of ring is at origin, find:




1) $\vec{E}\ at\ x = 80\ cm.$

2) $force\ \left(\vec{F}\right)\ on\ q=-5\mu C\ at\ x=80\ cm.$

Solution:

1) $E_b = \frac{kQx}{(a^2+R^2)^{3/2}} \Rightarrow\ E_b\ =\ \frac{9*10^9*0.25*10^{-9}*80*10^{-2}}{((5*10^{-2})^2+(80*10^{-2})^2)^{3/2}}$

$E_b = 3.495\ N/C\ \left(\hat{i}\right)$

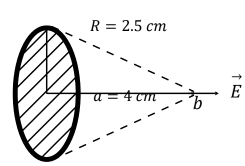
2) $F = Eq \Rightarrow F =\ 3.495*5*10^{-6}\ \Rightarrow\ F =\ 17.475\ \mu N\ \left(-\hat{i}\right)$

Ex4: charge $Q = 13\ nC$ is distributed uniformly on face of disk of radius 2.5 $cm$ , find $\vec{E}$ in point it is 4 $cm$ away from disk center?

$\sigma = Q/A, A = \pi R^2$

$\sigma = \frac{13*10^{-9}}{3.14*(2.5*10^{-2})^2}$

$\sigma = 6.6*10^{-6}\ C/m^2$



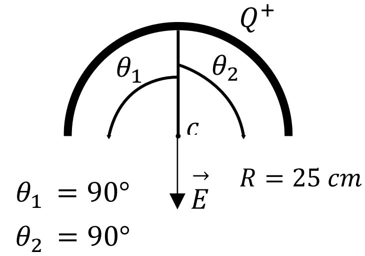

Solution:

$E_b = 2\pi k\sigma\left[1-\frac{a}{\sqrt{R^2+a^2}}\right]$

$E_b = 2*3.14*9*10^9*6.6*10^{-6}[1-\frac{4*10^{-2}}{\sqrt{(2.5*10^{-2})^2+(4*10^{-2})^2}}]$

$E_b = 56.909*10^3\frac{N}{C}\left(\hat{i}\right)$

Ex5: the charge density is 56 $nC/m$ it distributed on semi-circle with radius 25 $cm$ , find $\vec{E}$ in the center of semi-circle?



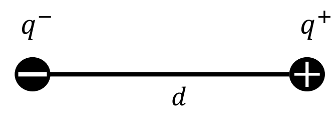

Solution:

$E_c = \frac{k\lambda}{R}[\sin\theta_1 + \sin\theta_2] \Rightarrow E_c = \frac{9*10^9*56*10^{-9}}{25*10^{-2}}[\sin 90° + \sin 90°]$

$E_c = 4.032*10^3\ N/C\ \left(-\hat{J}\right)$

**Electric dipole:**

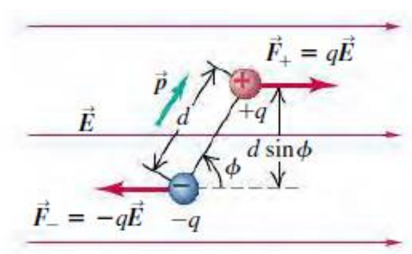
Electric dipole: A pair of point charges with same magnitude and opposite sign (positive and negative) separated by a distance d (زوج من الشحنات النقطية لهم نفس القيمة وعكس الإشارة تفصل بينهما مسافة).




Electric dipole moment $\vec{p} \Rightarrow p = qd$ , unit of $[p]$: $C.m$

Direction of $p$ from negative charge $q^-$ toward positive charge $q^+$(من الشحنة السالبة إلى الشحنة الموجبة).

Electric dipole in uniform $\vec{E}$ :




The two force in figure shown will generate torque ($\tau$). perpendicular

$\tau = \vec{F}\ X\ \vec{r}$

$r$: *the perpendicular distance between the lines of two* forces (المسافة العمودية بين النقطتين).

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

$\sin\phi = \frac{r}{d} \Rightarrow r = d\sin\phi$

$\tau = qE(d\sin\phi), p = qd \Rightarrow \tau = pE\sin\phi$

$\tau = \vec{p}\ X\ \vec{E}$, *cross product*

Potential energy of electric diploe ($U$):

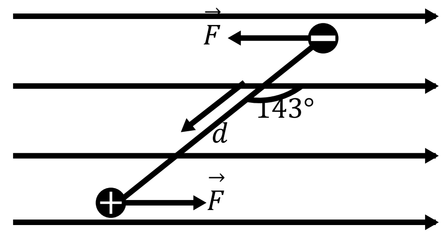
$dw = \tau d\phi \Rightarrow dw = -pE\sin\phi d\phi$

$$W = \int_{\phi_1}^{\phi_2} (-pE\sin\phi)\, d\phi \Rightarrow W = pE\cos\phi_2 - pE\cos\phi_1$$

*The work is negative of change of Potential energy.

$U(\phi) = -pE\cos\phi \Rightarrow U = -\vec{p}\,.\vec{E}$, *dot product*

Ex: in figure shown if magnitude of $\vec{E} = 15 * 10^5 N/C$ and two electric charges in electric dipole are $(\pm 3.2 * \ 10^{-19} C)$ and distance between charges $d = 0.125\ nm$,find:




1) electric dipole moment $\vec{p}$.

2) $torque(\tau)$ of dipole in $\vec{E}$.

3) the potential energy $(U)$ of dipole in $\vec{E}$.

Solution:

1) $p = qd \Rightarrow \ p = 3.2 * \ 10^{-19} * 0.125 * 10^{-9}$

$p = 4 * 10^{-29} C.m \ (from\ q^{-}\ toward\ q^{+})$

2) $\tau = \vec{p}\ X\ \vec{E} \Rightarrow \tau = pE\sin\phi$

$\tau = 4 * 10^{-29} * 15 * 10^5\ sin143°$

$\tau = 3.61 * 10^{-23}\ N.m\ (counter\ clockwise)$

3) $U = -\vec{p}\ .\vec{E} \ \ \Rightarrow \ U = -pEcos\phi$

$U = -4 * 10^{-29} * 15 * 10^5\ cos143°$

$U = 4.79 * \ 10^{-23}\ Jol$

## أهم القوانين

**The principle of quantization of the charge**

$q = ne$

**قانون كولوم:**

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

**المجال الكهربائي:**

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

**المجال الكهربائي الناشئ من شحنة نقطية:**

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

**المجال الكهربائي المنتظم:**

$$E = \frac{6}{\epsilon_0}$$

$F = am = E * q$

**المجال الكهربائي لتوزيع الشحنات:**

1)Rod:

a)( Rod) المجال الكهربائي على محور

$$E_b = k\frac{\lambda l}{a(a+l)}$$

b) finite rod:

$$E_b = \frac{2k\lambda \sin\theta}{a} \ or\ E_b = \frac{k\lambda l}{a\sqrt{a^2 + l^2/4}}$$

c)infinite rod:

$$E_b = \frac{2k\lambda}{a}$$

2) ring:

$$E_b = \frac{kQx}{(x^2 + a^2)^{3/2}}$$

$$E_c = 0$$

3)disk:

$$E_b = 2\pi k\sigma\left[1 - \frac{a}{\sqrt{R^2 + a^2}}\right]$$

4) semi-circle:

$$E_c = \frac{k\lambda}{R}[\sin\theta_1 + \sin\theta_2]$$

Electric dipole

$\tau = qE(d\sin\phi)$

$p = qd$

$\tau = pE\sin\phi$

Potential energy of electric diploe ($U$):

$U(\phi) = -pEcos\phi$

# Problems

**Book & more**

1-What is the number of electrons that should be added to a conductor to give it charge of $152 * 10^{-18} C$?

a)95000 b) None c)4.75 e21 d)950 e)1900

$q = ne$

$152 * 10^{-18} = n * 1.6 * 10^{-19}$

$n = 950$

2- How many electrons would have to be removed from or add to a sphere to leave it with a $charge\ of\ 4.46\ nc$?

a)$2.79 * 10^{10}$, electron removed. b) none c) 4.46*$10^{10}$, electron removed
d) 2.79*$10^{13}$, electron added e) 2.79*$10^{10}$, electron added

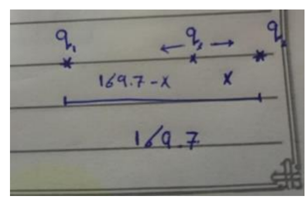
3- Two-point particles of charges $q_1 = 5.84 nC$ AND $q_2 = 2.89 nC$ are placed on $x_1 = 0\ mm$ and $x_2 = 169.7\ mm$ respectively. At what position on x-axis a third charge $q_3 = 1.4\ nC$ can be placed in such that the its net electrostatic force in zero?

a)$136.317\ mm$ b) $56.178\ mm$ c) $70.080\ mm$ d) $99.620\ mm$ e) $113.522\ mm$

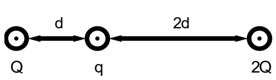
$F_1 = F_2$

$$k \frac{|q_1\ q_3|}{(169.7 - x)^2} = k \frac{|q_2\ q_3|}{x^2}$$

$x = 70.080\ mm$




4- In the figure, if Q = 30 µC, q = 5.0 µC, and d = 30 cm, what is the magnitude of the electrostatic force on q?




a. 15 N b. 23 N c. zero d. 7.5 N e. 38 N

5-Two small spheres spaced 20.0 cm apart have equal charge. How many excess electrons must be present on each sphere if the magnitude of the force of repulsion between them is 3.33 * $10^{-21}$ N?

Answer: …………

$$F = k \frac{|Q^2|}{{r_1}^2} \rightarrow Q = 1.2 * 10^{-16} \rightarrow Q = ne$$

n=760

حدد وجدد نيتك لله تعالى وحده دون سواه، في الطلب والمعرفة

6- Three point charges placed in $xy - plane$ such that $q_1 = 3.7\mu C$ at ($x = 0\ m\ and\ y = 0\ m$) $q_2 = 7.8\ \mu C$ at ($x = 0.14\ m\ and\ y = 0\ m$) and $q_3 = 16.65\mu C$ at ($x = 0.14\ m\ and\ y = 0.14\ m$). What is the magnitude of electrostatic force (in $N$ on charge 2?

a)61088.89 $N$ b) 61.089 $N$ c) 8.552 $N$ d) 31.079 $N$ e) 281.606$N$

$$F_1 = k\frac{|q_1\ q_2|}{{r_1}^2} = 9 * 10^9\frac{|3.7 *\ 7.8 * 10^{-12}|}{0.14^2} = 13.25$$

$$F_2 = k\frac{|q_2\ q_3|}{{r_2}^2} = 9 * 10^9\frac{|15.65 *\ 7.8 * 10^{-12}|}{0.14^2} = 59.63$$

$$F_{NET} = \sqrt{{F_1}^2 + {F_2}^2} = 61.088$$

7-Three-point charges are arranged on a line. Charge q3 = +5.00-nC and is at the origin. Charge q2 =-3.00 nC and is at x = +4.00 cm. Charge q1 is at x = +2.00 cm. What is q1 (magnitude and sign) if the net force on q3 is zero?

Answer: …………

8- A point Q is placed at the origin. A second charge,2Q, is placed on the x-axis at x= -3m.

If Q=70μC, what is the magnitude of the electrostatic force on a third point charge, -Q, is placed on the y-axis at y=4 m?

$$F_1 = k\frac{|Q\ Q|}{{r_1}^2} = 2.756$$

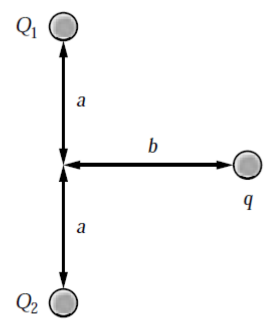
$$F_2 = k\frac{|2 * Q\ Q|}{{r_2}^2} = 3.528$$

$$F_{net} = \sqrt{{F_1}^2 + {F_2}^2 + 2 *\ F_1 *\ F_2 * cos\theta}$$

$$F_{net} = 5.98N$$

9- If a = 3.0 mm, b = 4.0 mm, Q1 = 60-nC, Q2 = 80-nC, and q = 32-nC in the figure, what is the magnitude of the total electric force on q?

a. 1.6 N b. 1.3 N c. 1.9 N d. 2.2 N e. 0.04 N



10-When two point charge are 0.04 cm apart, each one experiences a 1 N electric force due to the other charge. If they are moved to a new separation of 0.2 cm, the electric force on each of them is:

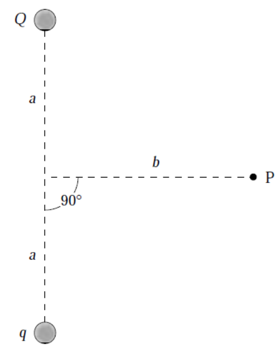
1)0.04 $N$ 2) 5 $N$ 3) 0.20 $N$ 4) 0.08 $N$ 5) 0.02$N$

11- A point charge $Q$ is placed at the origin. A second charge, $2Q$, is placed on the $x$ axis at $x = -3.0$ m. If $Q = 50\ \mu$C, what is the magnitude of the electrostatic force on a third point charge, $-Q$, placed on the $y$ axis at $y = +4.0$ m?

a. 3.0 N b. 2.5 N c. 3.7 N d. 4.4 N e. 1.8 N

12- If $a = 60$ cm, $b = 80$ cm, $Q = -6.0$ nC, and $q = 3.0$ nC in the figure, what is the magnitude of the electric field at point P?

a. 71 N/C b. 56 N/C c. 60 N/C d. 53 N/C e. 67 N/C

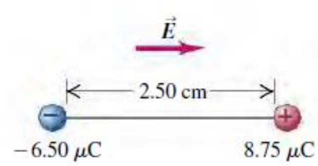



13- A +15-nC point charge is placed on the $x$ axis at $x = 1.5$ m, and a –20-nC charge is placed on the $y$ axis at $y = -2.0$m. What is the magnitude of the electric field at the origin?

a. 105 N/C b. 15 N/C c. 75 N/C d. 45 N/C e. 60 N/C

14- A +8.75 μC point charge is glued down on a horizontal frictionless table. It is tied to a -6.50 μC point charge by a light, nonconducting 2.50 cm wire. A uniform electric field of magnitude $1.85 * 10^8$ N/C is directed parallel to the wire, as shown in figure, Find the tension in the wire.

Answer: …………



15-When two point charge are 0.1 cm apart, each one experiences a 1 N electric force due to the other charge. If they are moved to a new separation of 0.27 cm, the electric force on each of them is:

1)0.69 $N$ 2) 0.27 $N$ 3) 0.14 $N$ 4) 1.46 $N$ 5) 0.87$N$

$$F_1 = k\frac{|q_1\, q_2|}{{r_1}^2}$$

$$F_2 = k\frac{|q_1\, q_2|}{{r_2}^2}$$

$$\frac{F_1}{F_2} = \frac{k\frac{|q_1\, q_2|}{{r_1}^2}}{k\frac{|q_1\, q_2|}{{r_2}^2}} \rightarrow F_2 = \frac{{r_1}^2}{{r_2}^2} = 0.14$$

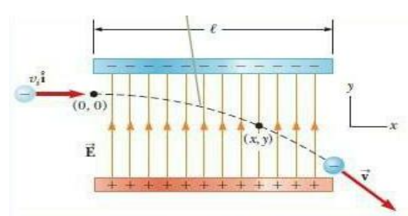
16-The point charge $(+6\mu C)$ is held fixed on the x axis at the $4\ cm$ mark, and similarly the point charge $(+12\mu C)$ is held fixed on the x axis at the $8\ cm$ mark. A tiny particle of charge ($(+3\mu C)$ is released from rest at $x\ = 0\ cm$. if the initial acceleration of the tiny particle is $100\ km.s^{-2}$ , what is the the particle's mass $(in\ g)$?

1)9.12 2)3.54 3)4.05 4)1.52 5)7.42

17- An electron enters the region of a uniform electric field as shown with $v_i = 8 * 10^6 m/s$ and E=284 N/C. the horizontal length of the plate is $l = 0.100m$.

a) what is the magnitude of elecron's acceleration while it is in the electric field

b) Assuming the electron enters the field at time t=0. Find the time at which it leaves the field.




$$F = am = E * q$$

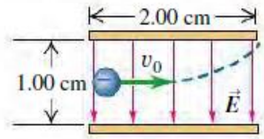
$$a * 9.1 * 10^{-31} = 284 * 1.6 * 10^{-19}$$

$$a = 4.99 * 10^{13}$$

$$t = \frac{l}{v_i} = \frac{0.1}{8 * 10^6} = 1.25 * 10^{-8} s$$

18- An electron is projected with an initial speed $v0 = 1.60 * 10^6$ m/s into the uniform field between two parallel plates in figure. Assume that the field between the plates is uniform and directed vertically downward and that the field outside the plates is zero. The electron enters the field at a point midway between the plates. If the electron just misses the upper plate as it emerges from the field, find the magnitude of the electric field.

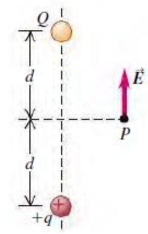
Answer: …………




19- An electron is moving east in a uniform electric field of 1.50 N/C directed to the west. At point *A*, the velocity of the electron is $4.50 * 10^5$ m/s toward the east. What is the speed of the electron when it reaches point *B*, 0.375 m east of point *A*?

Answer: …………

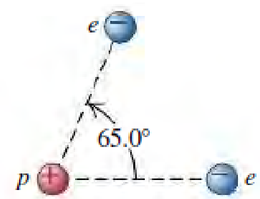
20- Two-point charges *Q* and +*q* (where *q* is positive) produce the net electric field shown at point *P* in figure The field points parallel to the line connecting the two charges. What can you conclude about the sign and magnitude of *Q*?




a. negative b. positive

21- If two electrons are each $1.50 * 10^{-10}$ m from a proton in figure, find the magnitude and direction of the net electric force they will exert on the proton.

Answer: …………




22- A small 12.3-g plastic ball is tied to a very light 28.6-cm string that is attached to the vertical wall of a room in figure. A uniform horizontal electric field exists in this room. When the ball has been given an excess charge of -1.11 mC, you observe that it remains suspended, with the string making an angle of 17.4° with the wall. Find the magnitude and direction of the electric field in the room.

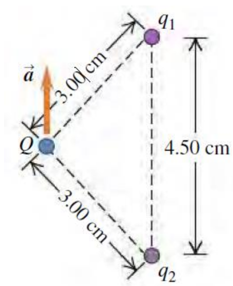
Answer: …………

23- A charge +$Q$ is located at the origin, and a charge +4$Q$ is at distance $d$ away on the $x$-axis. Where should a third charge, $q$, be placed, and what should be its sign and magnitude, so that all three charges will be in equilibrium?

Answer: …………

24- Two-point charges $q1$ and $q2$ are held in place 4.50 cm apart. Another point charge $Q$ = -1.75 $\mu$C, of mass 5.00 g, is initially located 3.00 cm from both charges in figure and released from rest. You observe that the initial acceleration of $Q$ is 324 $m/s^2$ upward, parallel to the line connecting the two-point charges. Find $q1$ and $q2$.

Answer: …………




25 A $5nC$ charge is distributed uniformly along the y axis from y=0 to y=2 m. which of the following integrals is correct for the x component of the electric field at x=6 m on the x axis?

a) $15\int_0^2 \frac{dy}{(36+y^2)^{\frac{3}{2}}}$

b) $135\int_0^2 \frac{dy}{(36+y^2)^{\frac{3}{2}}}$

c) $135\int_0^6 \frac{dy}{(36+y^2)^{\frac{3}{2}}}$

d) $270\int_0^2 \frac{dy}{(36+y^2)^{\frac{3}{2}}}$

e) $270\int_0^6 \frac{dy}{(36+y^2)^{\frac{3}{2}}}$

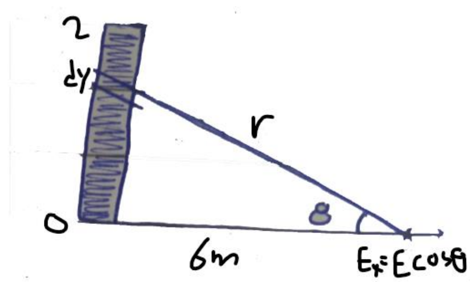
$L = 2 \qquad \lambda = \frac{Q}{L} = \frac{5*10^{-9}}{2} = 2.5n$

$dq = \lambda dl = 2.5*10^{-9}dy$

$r = \sqrt{36+y^2} \qquad \cos\theta = \frac{6}{\sqrt{36+y^2}}$

$E = \int_{y_1}^{y_2} k\frac{dq}{r^2} = \int_0^2 9*10^9\frac{2.5*10^{-9}dy}{(36+y^2)}$

$E_x = E*\cos\theta = \int_0^2 9*10^9\frac{2.5*10^{-9}dy}{(36+y^2)}*\frac{6}{\sqrt{36+y^2}} = 135\int_0^2\frac{dy}{(36+y^2)^{\frac{3}{2}}}$




26- A charge of 80 $n$C is uniformly distributed along the $x$ axis from $x$ = 0 to $x$ = 2.0 m. Determine the magnitude of the electric field at a point on the $x$ axis with $x$ = 8.0 m.

**a.** 30 N/C **b.** 15 N/C **c.** 48 N/C **d.** 90 N/C **e.** 60 N/C

27 A rod (length L= 6 m) is uniformly charged and has a total charge of 30 $nC$. What is the magnitude of the electric field at a point which lies along the axis of the rod and is d=6 m from the center of the rod?

a)5 N/C

b)10 N/C

c)20 N/C

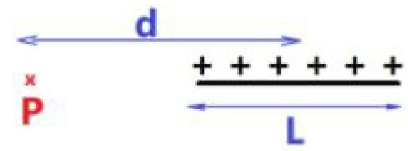
d)1.667 N/C

e)3.162 N/C

$$L = 6 \qquad a = 3 \qquad Q = \lambda l$$

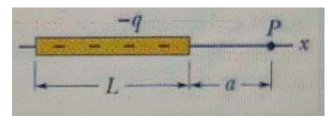
$$E_p = k\frac{\lambda l}{a(a+l)} = 9 * 10^9 \frac{30 * 10^{-9}}{3(3+6)}$$

$$E_p = 10 \text{ N/C}$$




28-A nonconducting rod of length 93 cm has charge -8.9 nC uniformly distributed along its length. What is the magnitude of the electric field produced at the point p at a distance 46 cm from the rod as shown on the figure?

1)125 N/C  2) 37 N/C  3) 0.0125 N/C  4) 5760 N/C  5) 877 N/C




29- A charge (uniform linear density = 9.0 nC/m) is distributed along the $x$ axis from $x = 0$ to $x = 3.0$ m. Determine the magnitude of the electric field at a point on the $x$ axis with $x = 4.0$ m.

**a.** 81 N/C  **b.** 74 N/C  **c.** 61 N/C  **d.** 88 N/C  **e.** 20 N/C

30-A charge of 25 nC is uniformly distributed along a circular arc (radius = 2.0 m) that is subtended by a 90 degree angle. What is the magnitude of the electric field at the center of the circle along which the arc lies?

**a.** 81 N/C  **b.** 61 N/C  **c.** 71 N/C  **d.** 51 N/C  **e.** 25 N/C

31- A 16-nC charge is distributed uniformly along the $x$ axis from $x = 0$ to $x = 4$ m. Which of the following integrals is correct for the magnitude (in N/C) of the electric field at $x = +10$ m on the $x$ axis?

a. $\int_0^4 \frac{36dx}{(10-x)^2}$  b. $\int_0^4 \frac{154\,dx}{(10-x)^2}$  c. $\int_0^4 \frac{36dx}{(x)^2}$  d. $\int_0^4 \frac{154dx}{(x)^2}$  e. none of these

32- A 12-nC charge is distributed uniformly along the *y* axis from *y* = 0 to *y* = 4 m. Which of the following integrals is correct for the *x* component of the electric field at *x* = 2 m on the *x* axis?

a. $\int_0^4 \frac{216dy}{(4+y^2)^{3/2}}$ b. $\int_0^4 \frac{54dy}{(4+y^2)^{3/2}}$ c. $\int_0^4 \frac{108dy}{4+y^2}$ d $\int_0^4 \frac{27dy}{4+y^2}$ e. none of these

33- A uniform linear charge of 2.0 nC/m is distributed along the *x* axis from *x* = 0 to *x* = 3 m. Which of the following integrals is correct for the *x* component of the electric field at *y* = 2 m on the *y* axis?

a. $\int_0^3 \frac{-18xdx}{(4+x^2)^{3/2}}$ b. $\int_0^3 \frac{-18dx}{(2+x)^2}$ c. $\int_0^3 \frac{-18dx}{4+x^2}$ d. $\int_0^3 \frac{-18xdx}{(2+x^2)^3}$ e. none of these

34-A linear charge of uniform density equal to 8.0 nC/m is distributed along the *x* axis from *x* = –2.0 m to *x* = 3.0 m. What is the magnitude of the electric field at the point *x* = 6.0 m on the *x* axis?

**a.** 60 N/C **b.** 10 N/C **c.** 26 N/C **d.** 15 N/C **e.** 45 N/C

35- A uniform linear charge of 2.0 nC/m is distributed along the *x* axis from *x* = 0 to *x* = 3 m. What is the *x* component of the electric field at *y* = 2 m on the *y* axis?

**a.** –5.0 N/C **b.** –5.7 N/C **c.** –4.0 N/C **d.** –6.2 N/C **e.** –9.0 N/C

36- A particle (*q* = 3.0 mC, *m* = 20 g) has a speed of 20 m/s when it enters a region where the electric field has a constant magnitude of 80 N/C and a direction which is the same as the velocity of the particle. What is the speed of the particle 3.0 s after it enters this region?

**a.** 68 m/s **b.** 44 m/s **c.** 36 m/s **d.** 80 m/s **e.** 56 m/s

37-When an electron moves from rest against a uniform electric field a distance of 10 $cm$ it attains a speed v. if it moves an additional 10 $cm$, the final speed is:

1)0.7 v 2) 4 v 3) v 4) 1.4 v 5) 2 v

التسارع ثابت لأنه مجال منتظم.

أول حالة:

$$v_2{}^2 = v_1{}^2 + 2a\Delta L$$

$v_2 = v$ $v_1 = 0$ $\Delta L = 10\ cm$

$v_2{}^2 = v_1{}^2 + 2a\Delta L \rightarrow v^2 = 0 + 2a * 0.1$

$a = \frac{v^2}{0.2}$

الحالة الثانية:

$v_2 = v_f$ $v_1 = v$ $\Delta L = 10\ cm$

$v_2{}^2 = v_1{}^2 + 2a\Delta L \rightarrow v_f{}^2 = \text{v}^2 + 2\frac{v^2}{0.2} * 0.1$

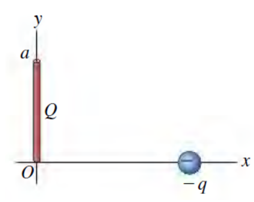
$v_f = 1.4\ v$

38- A particle ($m$ = 20 mg, $q$ = –5.0 C) moves in a uniform electric field of 60 N/C in the positive $x$ direction. At $t$ = 0, the particle is moving 25 m/s in the positive $x$ direction and is passing through the origin. How far is the particle from the origin at $t$ = 2.0 s?

**a.** 80 m **b.** 20 m **c.** 58 m **d.** 10 m **e.** 30 m

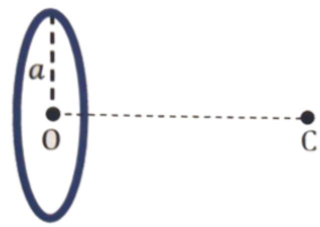
39-Positive charge $Q$ is distributed uniformly along the positive $y$-axis between $y$ = 0 and $y = a$. A negative point charge -$q$ lies on the positive $x$-axis, a distance $x$ from the origin in figure. Calculate the $x$- and $y$-components of the electric field produced by the charge distribution $Q$ at points on the positive $x$-axis.

Answer …………



40-A charge $Q = 3nC$ is uniformly distributed over a ring of radius $a = 6\ cm$. an electron is released from rest at pint c which is $8\ cm$ away from the center o of the ring. Find the speed ($in\ 10^6 m/s$) of the electron as it passes through point O. hint: $m_e = 9.11 * 10^{-31} kg$.

**a.** 7.95 **b.** 3.1 **c.** 5.13 **d.** 1.32 **e.** 0.23




$$E_b = \frac{kQx}{(x^2+a^2)^{\frac{3}{2}}} = \frac{9*10^9*3*10^{-9}*8*10^{-2}}{((8*10^{-2})^2+(6*10^{-2})^2)^{\frac{3}{2}}} = 2160$$

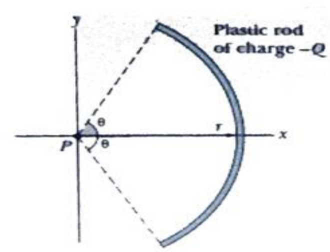
$am = E * q \to a = 3.78 * 10^{14}$

${v_2}^2 = 0 + 2 * 3.78 * 10^{14} * 8 * 10^{-2}$

$v_2 = 7.795$

41-A plastic rod with a linear charge density ($\lambda$) of 4.1*$10^{-7} C/m$ and total charge Q. it is bent a $2\theta°$ circular arc of radius 71 cm as shown in the figure. What is the magnitude the electric field due to the rod at point p when $\theta = 28°$?

a)4880 N/C b)1.56 N/C c)2440N/C d)3.45* $10^5$ N/C e)1260 N/C




42-A proton ($m = 1.67 * 10^{-27} kg$) is placed a distance y above a long, horizontal wire of linear charge density ($\lambda$). The proton is then released from rest. Determine the magnitude of the initial acceleration of the proton ($in\ m/s^2$). Take $\lambda = 2.8 * 10^{-12}\ c/m\ and\ y = 70cm$.

1)1.9*$10^7$ 2) 4.4*$10^7$ 3) 8.8*$10^6$ 4) 6.9*$10^6$ 5) 7.4*$10^6$

infinite rod: $E = \frac{2k\lambda}{y}$

$F = q * E = a * m$

$$a = q\frac{2k\lambda}{m*y} = 1.6*10^{-19}\frac{2*9*10^9*2.8*10^{-12}}{1.67*10^{-27}*70*10^{-2}}$$

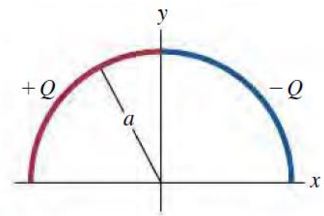
$a = 6.9 * 10^6$

43-A proton ($m = 1.67 * 10^{-27} kg$) is placed a distance y above a long, horizontal wire of linear charge density ($\lambda$). The proton is then released from rest. If the magnitude of the initial acceleration of the proton is ($0.52 * 10^7$) what is the value of in $\lambda$ ($c/m$) take $y = 40\ cm$.

1)2.2*$10^{-12}$ 2) 1.2*$10^{-11}$ 3) 2.2*$10^{-11}$ 4) 1.2*$10^{-12}$ 5) 2.2*$10^{-13}$

44- A semicircle of radius $a$ is in the first and second quadrants, with the center of curvature at the origin. Positive charge $+Q$ is distributed uniformly around the left half of the semicircle, and negative charge $-Q$ is distributed uniformly around the right half of the semicircle in figure. What are the magnitude and direction of the net electric field at the origin produced by this distribution of charge?

Answer …………



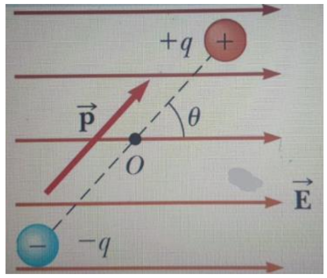

45-An electron dipole has opposite charges of $(5 * 10^{-15} C)$ separated by a distance of $0.4\ mm$. it is oriented at $(\theta = 60°)$ with respect to a uniform electric field of magnitude $(2 * 10^3\ N/C)$. The torque (in $N.m$) exerted on the dipole by the field is:

Solution:

$\tau = qEd\sin\theta$

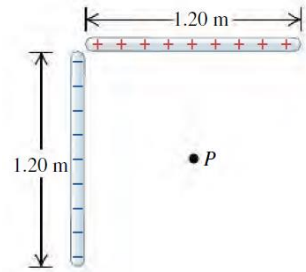
$\tau = 5 * 10^{-15} * 2 * 10^3 * 0.4 * 10^{-3} * \sin60°$

$\tau = 3.464 * 10^{-15}\ (clock\ wise)$




46- Two 1.20-m nonconducting rods meet at a right angle. One rod carries +2.50 $\mu$C of charge distributed uniformly along its length, and the other carries -2.50 $\mu$C distributed uniformly along it in figure. Find the magnitude and direction of the electric field these rods produce at point $P$, which is 60.0 cm from each rod.

Answer …………




47- When a positive charge $q$ is placed in the field created by two other charges $Q1$ and $Q2$, each a distance a away from $q$, the acceleration of $q$ is:

**a.** in the direction of the charge $Q1$ or $Q2$ of smaller magnitude.
**b.** in the direction of the charge $Q1$ or $Q2$ of greater magnitude.
**c.** in the direction of the negative charge if $Q1$ and $Q2$ are of opposite sign.
**d.** in the direction of the positive charge if $Q1$ and $Q2$ are of opposite sign.
**e.** in a direction determined by the vector sum of the electric fields of $Q1$ and $Q2$.

48- Two charged particles, $Q1$ and $Q2$, are a distance r apart. $Q2 = 5Q1$. Compare the forces they exert on each other. **F**1 is the force $Q2$ exerts on $Q1$. **F**2 is the force $Q1$ exerts on $Q2$.

**a.** **F**2 = 5**F**1. **b.** **F**2 = –5**F**1. **c.** **F**2 = **F**1. **d.** **F**2 = –**F**1. **e.** 5**F**2 = **F**1.

49-How long (in $ns$) does it take for an electron starts from rest to move a distance of 1 cm through a region with an electric field of $10^4\ N/C$

1)8.48 2)5.05 3)2.17 4)3.37 5)6.02

$F = E * q$

$F = 1.6 * 10^{-19} * 10^4 = 1.6 * 10^{-15}$

$F = am \rightarrow a = \frac{1.6 * 10^{-15}}{9.1 * 10^{-31}} = 1.75 * 10^{15}$

$\Delta L = t * v_1 + 0.5a\mathrm{t}^2 \rightarrow 1 * 10^{-2} = 0 + 0.5 * 1.75 * 10^{15} * \mathrm{t}^2$

$t = 3.37s$

**{Done by: Omar Mohammad}**

| | | | | | |
|---|---|---|---|---|---|
| 1. | d)950 | 11. | a. 3.0 N | 21. | 1.73*$10^{-8}$ $N$ , 32.5° |
| 2. | a | 12. | d. 53 N/C | 22. | 3.41∗ $10^4$ N/C, $(-\hat{i})$ |
| 3. | c) 70.080 $mm$ | 13. | c. 75 N/C | 23. | $q = -\frac{4Q}{9}(negative)$ |
| 4. | d. 7.5 N | 14. | 382 N | 24. | $q_1 = 5.37 * 10^{-8}C$, $q_2 = -6.11 * 10^{-8}C$ |
| 5. | 760 e | 15. | 3) 0.14 $N$ | 25. | b)135 $\int_0^2 \frac{dy}{(36+y^2)^{\frac{3}{2}}}$ |
| 6. | b) 61.089 $N$ | 16. | **4)1.54** | 26. | **b.** 15 N/C |
| 7. | + 0.75 nC | 17. | $a = 4.99 * 10^{13}$ $t = 1.25 * 10^{-8}s$ | 27. | b)10 N/C |
| 8. | 5.98$N$ | 18. | 364 N | 28. | 1)125 N/C |
| 9. | b. 1.3 N | 19. | $6.35 * 10^5 \text{m/s}$ | 29. | **c.** 61 N/C |
| 10. | 1)0.04 $N$ | 20. | a. negative | 30. | **d.** 51 N/C |
| 31 | a. $\int_0^4 \frac{36dx}{(10-x)^2}$ | 38 | **b.** 20 m | 45 | $\tau = 3.464 * 10^{-15}\ (clock\ wise)$ |
| 32 | b. $\int_0^4 \frac{54dy}{(4+y^2)^{3/2}}$ | 39 | $E = \frac{kQ}{x\sqrt{x^2+a^2}}\hat{i} - \frac{kQ}{a}\left[\frac{1}{x} - \frac{1}{\sqrt{x^2+a^2}}\right]\hat{j}$ | 46 | $E = 6.2 * 10^4\ N/C\ , \theta = 225°$ |
| 33 | a. $\int_0^3 \frac{-18xdx}{(4+x^2)^{3/2}}$ | 40 | $v_2 = 7.8$ | 47 | e |
| 34 | **d.** 15 N/C | 41 | a)4880 N/C | 48 | d |
| 35 | **c.** –4.0 N/C | 42 | 4) 6.9*$10^6$ | 49 | 4)3.37 s |
| 36 | **e.** 56 m/s | 43 | 4) 1.2*$10^{-12}$ | | |
| 37 | $v_f = 1.4\ v$ | 44 | $E = \frac{4kQ}{\pi a^2}\hat{i}$ | | |

# CHAPTER 22:

## GAUSS'S LAW

{Done by: Omar Mohammad}

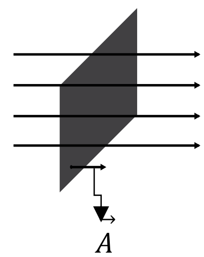
# Chapter 22: Gauss's Law

### Charge and electric flux (التدفق الكهربائي): $\phi$

"the number of electric field lines that flow a surface (عدد خطوط المجال الكهربائي التي تخترق سطح)".

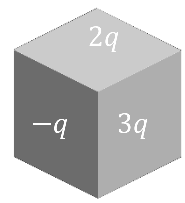
$\phi = \vec{E}\,.\vec{A}\,, \vec{A} : vector\ of\ area(perpendular\ of\ the\ surface)$ (العمودي على السطح هو متجه المساحة).

unit of $[\phi]$: $N.m^2/C$




**electric flux of closed surface (التدفق الكهربائي لسطح مغلق):**

$\phi = q_{enc}/\varepsilon_0$ , $q_{enc}$ :the total charge inside closed surface (مجموع الشحنات داخل سطح مغلق).

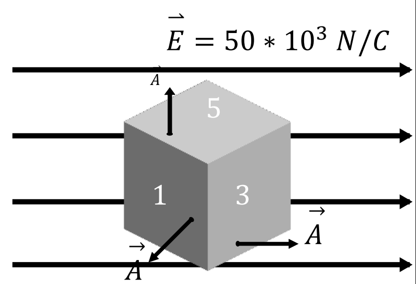



Ex1: three charges inside cube its dimensions $(2m, 2m, 2m)$, ( $q_1 = 20pC, q_2 = -60pC, q_1 = 50pC$), find electric flux ($\phi$)? ($\varepsilon_0 = 8.85 * 10^{-12}\ C^2/N.m^2$)

Solution:

$$\phi = q_{enc}/\varepsilon_0 \Rightarrow \phi = \frac{(20-60+50)*10^{-12}}{8.85*10^{-12}} \Rightarrow \phi = 1.129\ N.m^2/C$$

Ex2: in figure shown, find $\phi$:(side length= $2m$)




Solution:

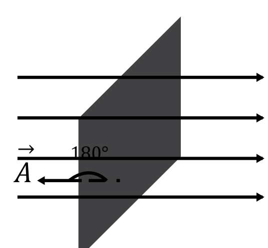
*the cube has 6 faces from (1-6):
 1,2: front and back
 3,4: sides
 5,6: top and bottom

$\vec{A}$ of faces 1,2 perpendicular to $\vec{E}$, then $\phi_{1,2} = 0$;because $\cos 90° = 0$

$\vec{A}$ of faces 1,2 parallel to $\vec{E}$, then:

$\phi_3 = \vec{E}\,.\vec{A} \Rightarrow \phi_3 = E\ A\ cos\theta, \theta = 0° \Rightarrow \phi_3 = 50 * 10^3 * (2 * 2)\cos 0°$
$\phi_3 = 200 * 10^3\ N.m^2/C$

$\phi_4 = \vec{E}\,.\vec{A} \Rightarrow \phi_4 = E\ A\ cos\theta, \theta = 180° \Rightarrow \phi_4 = 50 * 10^3 * (2 * 2)\cos 180°$
$\phi_4 = -200 * 10^3\ N.m^2/C$




$\vec{A}$ of faces 5,6 perpendicular to $\vec{E}$, then $\phi_{5,6} = 0$;because $\cos 90°$ =0

Ex3: square surface inside $\vec{E}$ with magnitude = $15 * 10^3 N/C$ , angle between $\vec{E}$ and surface =37°,find $\phi$: (side length= $3m$)
Solution:

$\phi = E\ A\ cos\theta, \theta = 53°$; because we take $\theta$ between $\vec{E}$ and $\vec{A}$ not between $\vec{E}$ and surface.

$\phi = 15 * 10^3 * (3 * 3) * \ cos53° \Rightarrow \phi = 81.245\ N.m^2/C$

## Gauss's Law:

"the total of electric flux $\phi$ through any closed surface (a surface enclosing a define volume) is proportional to the net electric charge divided to $\varepsilon_0$ inside the surface".
(قيمة التدفق لأي سطح مغلق تساوي نسبة الشحنات داخل السطح مقسومة على السماحية).

$$\phi = \oint E.dA = \frac{Q_{enc}}{\varepsilon_0}$$

Find electric field from gauss's law:

خطوات الحل باستخدام قانون غاوس:
1) نفرض سطح (سطح غاوس) مناسب لشكل توزيع الشحنات.
2) نحسب قيمة الشحنة داخل (سطح غاوس) الذي فرضناه.
3) نحسب مساحة سطح غاوس الذي فرضناه.
4) ثم نعوض داخل قانون غاوس.

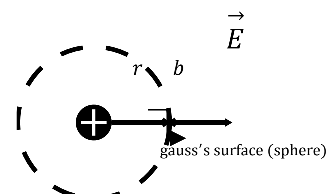
1) for a point charge:

$$\oint E.dA = \frac{Q_{enc}}{\varepsilon_0} \Rightarrow E \int dA = \frac{q}{\varepsilon_0}$$

التكامل يساوي مساحة سطح غاوس

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

$$E_b = \frac{q}{4\pi\varepsilon_0 (r^2)}$$




$* \int dA =$ gauss's surface area

$*$ area of sphere surface $= 4\pi r^2$

$* Q_{enc}$: the total charge inside gauss's surface

2) infinite line:

$$\oint E.dA = \frac{Q_{enc}}{\varepsilon_0} \Rightarrow E \int dA = \frac{\lambda l}{\varepsilon_0}$$

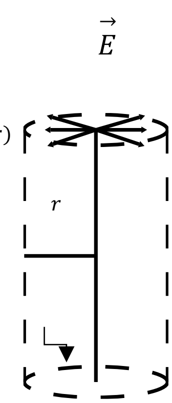
$$E(2\pi r l) = \frac{\lambda l}{\varepsilon_0}$$

$$E = \frac{\lambda}{2\pi\varepsilon_0 (r)} \text{ or } E = \frac{2k\lambda}{(r)}$$

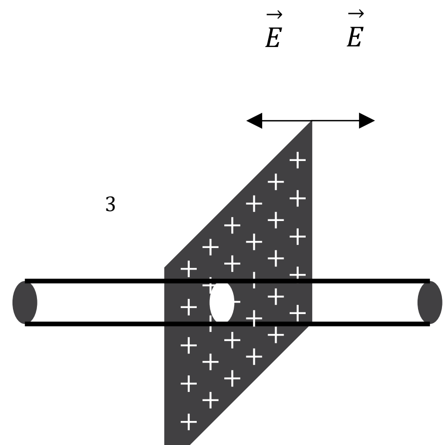
$* \int dA =$ gauss's surface area (*side area of cylinder*)

$*$ area of side surface of cylinder $= 2\pi r l$

$* Q_{enc}$: the distribution of charges a long line $(\lambda l)$



## {Done by: Omar Mohammad}




3) surface charge distribution: (sheet)

$$\oint E.dA = \frac{Q_{enc}}{\varepsilon_0}$$

$$\oint E.dA_1 + \oint E.dA_2 + \oint E.dA_3 = \frac{Q_{enc}}{\varepsilon_0}$$

$\oint E.dA_3 = 0$,because $\vec{E}$ perpendicular to $\vec{A}$ surface 3.

$$\oint E.dA_1 + \oint E.dA_2 = \frac{Q_{enc}}{\varepsilon_0}$$

$$E\int dA_1 + E\int dA_2 = \frac{\sigma A}{\varepsilon_0}$$

$$EA + EA = \frac{\sigma A}{\varepsilon_0} \Rightarrow 2EA = \frac{\sigma A}{\varepsilon_0}$$

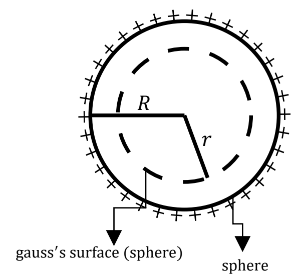
$$E = \frac{\sigma}{2\varepsilon_0}$$

* $Q_{enc}$: the distribution of charges a over surface ($\sigma A$)
* cylinder has 3 sides

### volume charges distribution:

1) conducting sphere: (في الأسطح الموصلة الشحنات تتوزع على السطح الخارجي)

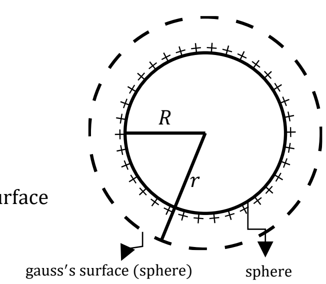
a) inside sphere r<R:




$$\oint E.dA = \frac{Q_{enc}}{\varepsilon_0}, \ Q_{enc} = 0 \ ; because\ no\ charge\ inside\ conducting\ sphere$$

$$E = 0$$

b) outside sphere r>R:



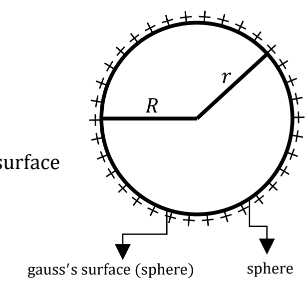

$$\oint E.dA = \frac{Q_{enc}}{\varepsilon_0}, \ Q_{enc} = q\ for\ sphere$$

$$E\int dA = \frac{q}{\varepsilon_0} \Rightarrow E(4\pi r^2) = \frac{q}{\varepsilon_0}$$

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

* $\int dA$ = gauss's surface area
* area of sphere surface = $4\pi r^2$
* $Q_{enc}$: the total charge inside gauss's surface

c)on surface r=R:




$$\oint E.dA = \frac{Q_{enc}}{\varepsilon_0}, \ Q_{enc} = q\ for\ sphere$$

$$E\int dA = \frac{q}{\varepsilon_0} \Rightarrow E(4\pi R^2) = \frac{q}{\varepsilon_0}$$

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

* $\int dA$ = gauss's surface area
* area of sphere surface = $4\pi R^2$
* $Q_{enc}$: the total charge inside gauss's surface

gauss's surface (cylinder)

من لوازم المُدارسة للعلم: إحسان قراءته وفهمه وحفظه

2) non- conducting sphere:

a) inside sphere r<R:

$$\oint E.dA = \frac{Q_{enc}}{\varepsilon_0}$$

$$E\int dA = \frac{q}{\varepsilon_0} \Rightarrow E(4\pi r^2) = \frac{qr^3}{R^3}/\varepsilon_0$$

$$E = \frac{qr}{4\pi\varepsilon_0 R^3}$$

or

$$E = \frac{\left(\rho\left(\frac{4}{3}\pi R^3\right)\right)r}{4\pi\varepsilon_0 R^3} \Rightarrow E = \frac{\rho r}{3\varepsilon_0}$$

$* \int dA =$ gauss's surface area

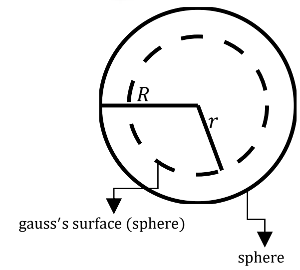
$*$ area of sphere surface $= 4\pi r^2$

The density of any object or part from it is equal.
(الكثافة لأي جسم أو جزء منه متساوي)

$* \rho = \rho$

$$\frac{q}{\frac{4}{3}\pi R^3} = \frac{q_{enc}}{\frac{4}{3}\pi r^3}$$

$$q_{enc} = \frac{qr^3}{R^3}, q = \rho\left(\frac{4}{3}\pi R^3\right)$$




b) outside sphere r>R:

$$\oint E.dA = \frac{Q_{enc}}{\varepsilon_0}, Q_{enc} = q \text{ for sphere}$$

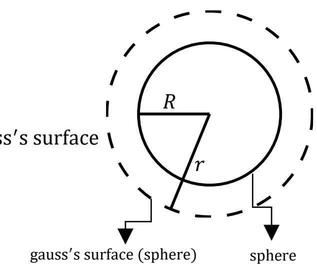
$$E\int dA = \frac{q}{\varepsilon_0} \Rightarrow E(4\pi r^2) = \frac{q}{\varepsilon_0}$$

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

$* \int dA =$ gauss's surface area

$*$ area of sphere surface $= 4\pi r^2$

$* Q_{enc}$: the total charge inside gauss's surface




c) on surface r=R:

$$\oint E.dA = \frac{Q_{enc}}{\varepsilon_0}, Q_{enc} = q \text{ for sphere}$$

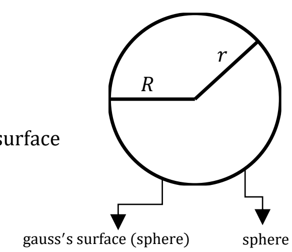
$$E\int dA = \frac{q}{\varepsilon_0} \Rightarrow E(4\pi R^2) = \frac{q}{\varepsilon_0}$$

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

$* \int dA =$ gauss's surface area

$*$ area of sphere surface $= 4\pi R^2$

$* Q_{enc}$: the total charge inside gauss's surface

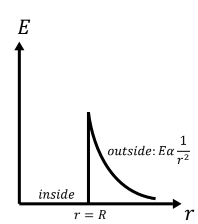



Relation between $E$ and $r$ for sphere:

1)conducting sphere:

inside sphere $E = 0$.

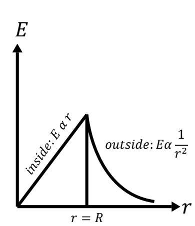
outside sphere $E \alpha \frac{1}{r^2}$.




2) non- conducting sphere:

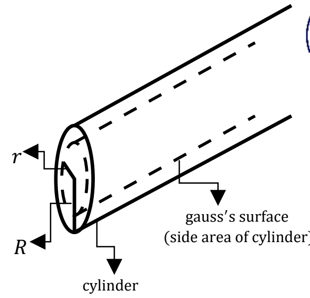
inside sphere $E \ \alpha \ r$.

outside sphere $E \ \alpha \ \frac{1}{r^2}$.



## {Done by: Omar Mohammad}

3) conducting infinite cylinder:




a) inside cylinder r<R:

$$\oint E.dA = \frac{Q_{enc}}{\varepsilon_0}, Q_{enc} = 0 \text{ ; because no charge inside conducting sphere}$$

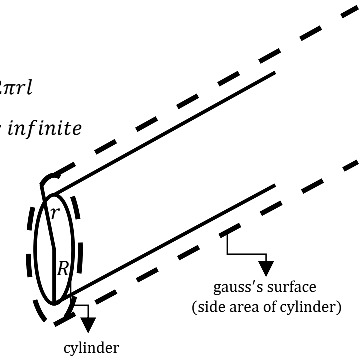
$$E = 0$$

b) outside cylinder r>R:

$* \int dA =$ gauss's surface area

$* \, side$ area of cylinder surface $= 2\pi rl$

$* \, Q_{enc} = \lambda l, \lambda; becuse\ cylinder\ is\ infinite$




$$\oint E.dA = \frac{Q_{enc}}{\varepsilon_0} \Rightarrow E\int dA = \frac{\lambda l}{\varepsilon_0}$$

$$E(2\pi rl) = \frac{\lambda l}{\varepsilon_0}$$

$$E = \frac{\lambda}{2\pi\varepsilon_0 (r)} \text{ or } E = \frac{2k\lambda}{(r)}$$

c) on surface r=R:

$$\oint E.dA = \frac{Q_{enc}}{\varepsilon_0}, Q_{enc} = q\ for\ sphere$$

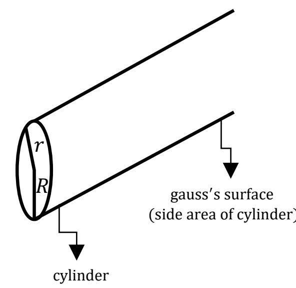
$$E\int dA = \frac{q}{\varepsilon_0} \Rightarrow E(2\pi Rl) = \frac{q}{\varepsilon_0}$$

$$E = \frac{\lambda}{2\pi\varepsilon_0(R)}$$

$* \int dA =$ gauss's surface area

$* \, side$ area of cylinder surface $= 2\pi Rl$

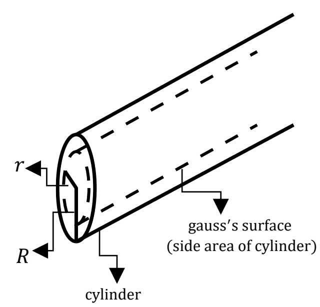
$* \, Q_{enc} = \lambda l, \lambda; becuse\ cylinder\ is\ infinite$




4) non-conducting infinite cylinder:

a) inside cylinder r<R:

$$\oint E.dA = \frac{Q_{enc}}{\varepsilon_0} \Rightarrow E\int dA = \frac{Q_{enc}}{\varepsilon_0}, Q_{enc} = \rho\pi R^2 l$$




$$E(2\pi rl) = \frac{\rho\pi r^2 l}{\varepsilon_0}$$

$$E = \frac{\rho r}{2\varepsilon_0}$$

b) outside cylinder r>R:

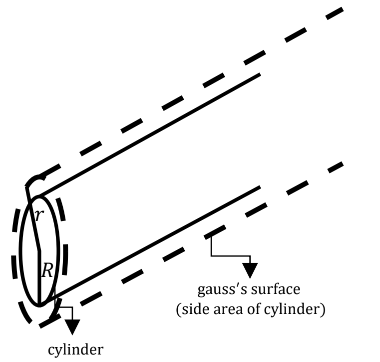
$$\oint E.dA = \frac{Q_{enc}}{\varepsilon_0} \Rightarrow E\int dA = \frac{Q_{enc}}{\varepsilon_0}, Q_{enc} = \rho\pi r^2 l$$

$$E(2\pi rl) = \frac{\rho\pi R^2 l}{\varepsilon_0}$$

$$E = \frac{\rho R^2}{2\varepsilon_0 r}$$

$* \int dA =$ gauss's surface area

$*$ *side* area of cylinder surface $= 2\pi rl$




c) on surface r=R:

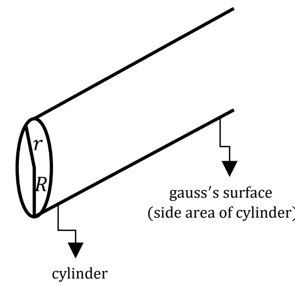
$$\oint E.dA = \frac{Q_{enc}}{\varepsilon_0} \Rightarrow E\int dA = \frac{Q_{enc}}{\varepsilon_0}, Q_{enc} = \rho\pi R^2 l$$

$$E(2\pi Rl) = \frac{\rho\pi R^2 l}{\varepsilon_0}$$

$$E = \frac{\rho R}{2\varepsilon_0}$$

$* \int dA =$ gauss's surface area

$*$ *side* area of cylinder surface $= 2\pi Rl$

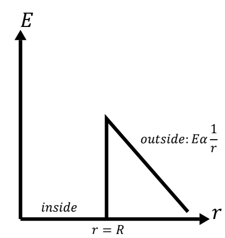



Relation between $E$ and $r$ for cylinder:

1)conducting cylinder:

inside cylinder $E = 0$.

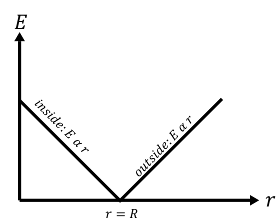
outside cylinder $E\alpha\frac{1}{r}$.




2) non- conducting cylinder:

Inside cylinder $E \ \alpha \ r$.

outside cylinder $E \ \alpha \ \frac{1}{r}$.

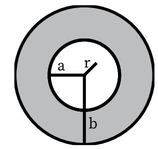


Ex: two spheres one conducting (radius a) inside one non- conducting (radius b), find $E$ if:

a) r<a.
b) a<r<b.
c) r>b.

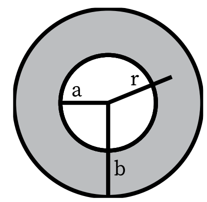
Solution:

1) $\oint E.dA = \frac{q_{enc}}{\varepsilon_0}, q_{enc} = 0$




$E = 0$

2) $\oint E.dA = \frac{q_{enc}}{\varepsilon_0} \Rightarrow q_{enc} = \rho V_{shell} \Rightarrow \; q_{enc} = \rho\left(\frac{4}{3}\pi r^3 - \frac{4}{3}\pi a^3\right)$

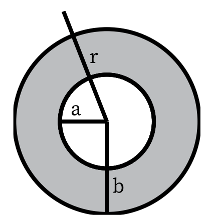



$E.\int dA = \frac{\rho\frac{4}{3}\pi(r^3-a^3)}{\varepsilon_0} \Rightarrow E.(4\pi r^2) = \frac{\rho\frac{4}{3}\pi(r^3-a^3)}{\varepsilon_0}$

$$E = \frac{\rho(r^3 - a^3)}{3\varepsilon_0.r^2}$$

3) $\oint E.dA = \frac{q_{enc}}{\varepsilon_0} \Rightarrow q_{enc} = \rho V_{shell} \Rightarrow \; q_{enc} = \rho\left(\frac{4}{3}\pi b^3 - \frac{4}{3}\pi a^3\right)$

$E.\int dA = \frac{\rho\frac{4}{3}\pi(b^3-a^3)}{\varepsilon_0} \Rightarrow E.(4\pi r^2) = \frac{\rho\frac{4}{3}\pi(b^3-a^3)}{\varepsilon_0}$




$$E = \frac{\rho(b^3 - a^3)}{3\varepsilon_0.r^2}$$

# Problems

**Book & more**

1- Charges $q$ and $Q$ are placed on the $x$ axis at $x = 0$ and $x = 2.0$ m, respectively. If $q = –40$ pC and $Q =$ +30 pC, determine the net flux through a spherical surface (radius = 1.0 m) centered on the origin.

a. –9.6 $N.m^2/C$ b. –6.8 $N.m^2/C$ c. –8.5 $N.m^2/C$ d. –4.5 $N.m^2/C$ e. –1.1 $N.m^2/C$

$\emptyset = \frac{q}{\varepsilon_\circ}$

$\emptyset = \frac{-40*10^{-12}}{8.85*10^{-12}} = -4.5\ N.m^2/C$

2- A uniform linear charge density of 4.0 nC/m is distributed along the entire $x$ axis. Consider a spherical (radius = 5.0 cm) surface centered on the origin. Determine the electric flux through this surface.

**a.** 68 $N.m^2/C$ **b.** 62 $N.m^2/C$ **c.** 45 $N.m^2/C$ **d.** 79 $N.m^2/C$ **e.** 23 $N.m^2/C$

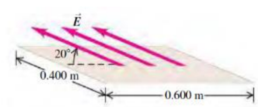
$\emptyset = \frac{\lambda*2r}{\varepsilon_\circ} = \frac{4*10^{-9}*10*10^{-2}}{8.85*10^{-12}} = 45 N.m^2/C$

3- Charge of uniform surface density (4.0 nC/$m^2$) is distributed on a spherical surface (radius = 2.0 cm). What is the total electric flux through a concentric spherical surface with a radius of 4.0 cm?

**a.** 2.3 $N.m^2/C$ **b.** 1.7 $N.m^2/C$ **c.** 2.8 $N.m^2/C$ **d.** 4.0 $N.m^2/C$ **e.** 9.1 $N.m^2/C$

4-A flat sheet is in the shape of a rectangle with sides of lengths 0.400 m and 0.600 m. The sheet is immersed in a uniform electric field of magnitude 90.0 N/C that is directed at 20° from the plane of the sheet in figure. Find the magnitude of the electric flux through the sheet.

Answer: ………….




5-You measure an electric field of $1.25 * 10^6$ N/C at 0.150 m from a point charge. There is no other source of electric field in the region other than this point charge. What is the electric flux through the surface of a sphere that has this charge at its center and that has radius 0.150 m?

Answer: ………….

$E = \frac{kq}{r^2} \rightarrow q = \frac{Er^2}{k} = 3.125 * 10^{-6}$

$\emptyset = \frac{q}{\varepsilon_\circ} = 3.5 * 10^5$

6-A point charge $q1 = 4.00$ nC is located on the $x$-axis at $x = 2.00$ m, and a second point charge $q2 = -6.00$ nC is on the $y$-axis at $y = 1.00$ m. What is the total electric flux due to these two-point charges through a spherical surface centered at the origin and with radius?

1) 0.500 m

2) 1.50 m

3) 2.50 m

Answer: ………….

7-A hemispherical surface (half of a spherical surface) of radius $R$ is in a uniform electric field of magnitude $E$ that is parallel to the axis of the hemisphere. What is the magnitude of the electric flux through the hemisphere surface?

**a.** $\pi R^2 E/3$ **b.** $4\pi R^2 E/3$ **c.** $2\pi R^2 E/3$ **d.** $\pi R^2 E/2$ **e.** $\pi R^2 E$

8-Charge of uniform surface density (0.20 nC/$m^2$) is distributed over the entire *xy* plane. Determine the magnitude of the electric field at any point having z = 2.0 m.

**a.** 17 N/C **b.** 11 N/C **c.** 23 N/C **d.** 28 N/C **e.** 40 N/C

$$E = \frac{\sigma}{2 * \varepsilon_\circ} = 11\text{N/C}$$

9-Charge of a uniform density (8.0 nC/$m^2$) is distributed over the entire *xy* plane. A charge of uniform density (5.0 nC/$m^2$) is distributed over the parallel plane defined by z = 2.0 m. Determine the magnitude of the electric field for any point with z = 1.0 m.

**a.** 730 N/C **b.** 450 N/C **c.** 280 N/C **d.** 170 N/C **e.** 340 N/C

10-A solid metal sphere with radius 0.450 m carries a net charge of 0.250 nC. Find the magnitude of the electric field at a point 0.100 m outside the surface of the sphere.

Answer: ………….

$$E = \frac{q}{4 * \pi * \varepsilon_\circ * r^2}$$

$$E = \frac{0.25 * 10^{-9}}{4 * \pi * \varepsilon_\circ * (0.45 + 0.1)^2} = 7.44\ N/C$$

11- The electric field 0.400 m from a very long uniform line of charge is 840 N/C. How much charge is contained in a 2.00-cm section of the line?

Answer: ………….

12- The electric field at 0.145 m from the surface of a solid insulating sphere with radius 0.355 m is 1750 N/C Assuming the sphere's charge is uniformly distributed, what is the charge density inside it?

Answer: ………….

13- Charge $Q$ is distributed uniformly throughout the volume of an insulating sphere of radius $R$ = 4.00 cm. At a distance of $r$ = 8.00 cm from the center of the sphere, the electric field due to the charge distribution has magnitude $E$ = 940 N/C. What are the volume charge density for the sphere?

$$E = \frac{q}{4 * \pi * \varepsilon_\circ * r^2} \rightarrow = \frac{\rho * V}{4 * \pi * \varepsilon_\circ * r^2}$$

$$940 = \frac{\rho * \frac{4 * \pi * (4 * 10^{-2})^3}{3}}{4 * \pi * \varepsilon_\circ * (8 * 10^{-2})^2}$$

$$\rho = 2.5 * 10^{-6}$$

14-Each 2.0-m length of a long cylinder (radius = 4.0 mm) has a charge of 4.0 nC distributed uniformly throughout its volume. What is the magnitude of the electric field at a point 5.0 mm from the axis of the cylinder?

**a.** 7.2 kN/C **b.** 8.1 kN/C **c.** 9.0 kN/C **d.** 9.9 kN/C **e.** 18 kN/C

15-A long cylindrical shell (radius = 2.0 cm) has a charge uniformly distributed on its surface. If the magnitude of the electric field at a point 8.0 cm radially outward from the axis of the shell is 85 N/C, how much charge is distributed on a 2.0-m length of the charged cylindrical surface?

**a.** 0.38 nC **b.** 0.76 nC **c.** 0.19 nC **d.** 0.57 nC **e.** 0.98 nC

$$E = \frac{\lambda}{2 * \pi * \varepsilon_\circ * r^2}$$
$$\lambda = 3.781 * 10^{-10}$$
$$q = \lambda * l = 3.781 * 10^{-10} * 2$$
$$q = 0.76nC$$

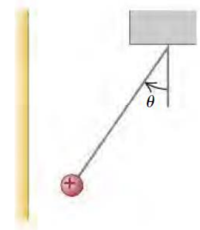
16- A square insulating sheet 80.0 cm on a side is held horizontally. The sheet has 4.50 nC of charge spread uniformly over its area. Calculate the electric field at a point 0.100 mm above the center of the sheet.

Answer: ………….

17-A very small object with mass $8.20 * 10^{-9}$and positive charge $6.50 * 10^{-9}$C is projected directly toward a very large insulating sheet of positive charge that has uniform surface charge density $5.90 * 10^{-8}$ C/$m^2$. The object is initially 0.400 m from the sheet. What initial speed must the object have for its closest distance of approach to the sheet to be 0.100 m?

Answer: ………….

18-A small sphere with mass 4.00 $*10^{-6}$ kg and charge 5.00 $* 10^{-8}$ C hangs from a thread near a very large, charged insulating sheet in figure. The charge density on the surface of the sheet is uniform and equal to -2.50 $* 10^{-9}$ $C/m^2$. Find the angle of the thread.




Answer: ………….

19-Charge of uniform density (20 $nC/m^2$) is distributed over a cylindrical surface (radius = 1.0 cm), and a second coaxial surface (radius = 3.0 cm) carries a uniform charge density of –12 $nC/m^2$. Determine the magnitude of the electric field at a point 4.0 cm from the symmetry axis of the two surfaces.

**a.** 0.45 kN/C **b.** 1.0 kN/C **c.** 0.73 kN/C **d.** 0.56 kN/C **e.** 2.3 kN/C

$E * A_{\text{غاوز}} = \frac{Q_{totel}}{\varepsilon_\circ}$
$A_{\text{غاوز}} = 2 * \pi * r * l$
$Q_{totel} = (\sigma_1 A_1 + \sigma_2 A_2)$
$E = 0.45\text{kN/C}$

20-A charge of 5.0 pC is uniformly distributed throughout the volume between concentric spherical surfaces having radii of 1.0 cm and 3.0 cm. What is the magnitude of the electric field 2.0 cm from the center of the surfaces?

**a.** 33 N/C **b.** 113 N/C **c.** 30 N/C **d.** 450 N/C **e.** 47 N/C

21-A charge of 8.0 pC is distributed uniformly on a spherical surface (radius = 2.0 cm), and a second charge of –3.0 pC is distributed uniformly on a concentric spherical surface (radius = 4.0 cm). Determine the magnitude of the electric field 5.0 cm from the center of the two surfaces.

**a.** 14 N/C **b.** 11 N/C **c.** 22 N/C **d.** 18 N/C **e.** 40 N/C

$E * A_{\text{غاوز}} = \frac{Q_{totel}}{\varepsilon_\circ}$
$E * 4 * \pi * (5 * 10^{-2})^2 = \frac{8-3}{8.85 * 10^{-12}}$
$E = 18$

22- A long line carrying a uniform linear charge densit+50.0 $\mu C/m$ runs parallel to and 10.0 cm from the surface of a large, flat plastic sheet that has a uniform surface charge density of -100 0 $\mu C/m^2$ on one side. Find the location of all points where an $\alpha$ particle would feel no force due to this arrangement of charged objects.

Answer: ………….

لابد بعد كل تدريب من تجريب، وبعد كل حفظ من تثبيت، وبعد كل مرحلة علمية من تقييم

23-A surface charge of uniform density 3.0 nC/$m^2$ is placed on a spherical surface which has a radius of 2.0 mm. A uniform surface charge (density = –10 nC/$m^2$) is placed on a concentric spherical surface (radius = 8.0 mm). What is the magnitude of the electric field 5.0 mm from the center of these surfaces?

**a.** 63 N/C **b.** 54 N/C **c.** 72 N/C **d.** 45 N/C **e.** 36 N/C

24-The field just outside the surface of a long conducting cylinder which has a 2.0-cm radius points radially outward and has a magnitude of 200 N/C. What is the charge density on the surface of the cylinder?

**a.** 2.7 nC/$m^2$ **b.** 0.9nC/$m^2$ **c.** 3.5 nC/$m^2$ **d.** 4.4 nC/$m^2$ **e.** 1.8 nC/$m^2$

25-A long cylindrical conductor (radius = 1.0 mm) carries a charge density of 4.0 pC/m and is inside a coaxial, hollow, cylindrical conductor (inner radius = 3.0 mm, outer radius = 4.0 mm) that has a total charge of –8.0 pC/m. What is the magnitude of the electric field 2.0 mm from the axis of these conductors?

**a.** 24 N/C **b.** 18 N/C **c.** zero **d.** 36 N/C **e.** 226 N/C

$$EA = \frac{Q}{\varepsilon_\circ}$$

$$E * 2 * \pi * 2 * 10^{-3} * l = \frac{4 * 10^{-12} * l}{8.85 * 10^{-12}}$$

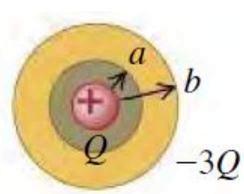
$$E = 36$$

26-A point charge of 6.0 nC is placed at the center of a hollow spherical conductor (inner radius = 1.0 cm, outer radius = 2.0 cm) which has a net charge of –4.0 nC. Determine the resulting charge density on the inner surface of the conducting sphere.

**a.** +4.8 $\mu$C/$m^2$ **b.** –4.8 $\mu$C/$m^2$ **c.** –9.5 $\mu$C/$m^2$ **d.** +9.5 $\mu$C/$m^2$ **e.** –8.0 $\mu$C/$m^2$

27- A conducting spherical shell with inner radius (*a)* and outer radius (*b)* has a positive point charge *Q* located at its center. The total charge on the shell is -3*Q*, and it is insulated from its surroundings in figure. Derive expressions for the electric field magnitude *E* in terms of the distance *r* from the center for the regions r<a, a<r<b, and r>b.

Answer: ………….




28- Negative charge -*Q* is distributed uniformly over the surface of a thin spherical insu[lating shell with] radius *R*. Calculate the force (magnitude and direction) that the shell exerts on a positive point charge *q* located a distance *r* >*R* from the center of the shell (outside the shell).

Answer: ………….

29- A small metal sphere is suspended from the conducting cover of a conducting metal ice bucket by a non-conducting thread. The sphere is given a negative charge before the cover is placed on the bucket. The bucket is tilted by means of a non-conducting material so that the charged sphere touches the inside of the bucket. Which statement is correct?

**a.** The negative charge remains on the metal sphere.
**b.** The negative charge spreads over the outside surface of the bucket and cover.
**c.** The negative charge spreads over the inside surface of the bucket and cover.
**d.** The negative charge spreads equally over the inside and outside surfaces of the bucket and cover.
**e.** The negative charge spreads equally over the sphere and the inside and outside surfaces of the bucket and cover.

30- An uncharged metal sphere is placed on an insulating puck on a frictionless table. A rod with a charge $q$ is brought close to the sphere but does not touch it. As the rod is brought in, the sphere.

**a.** remains at rest.
**b.** moves toward the rod.
**c.** moves away from the rod.
**d.** moves perpendicular to the velocity vector of the rod.
**e.** moves upward off the puck.

| | | | | | |
|---|---|---|---|---|---|
| 1. | d. –4.5 $N.m^2/C$ | 11. | 3.74*$10^{-10}C$ | 21. | **d.** 18 N/C |
| 2. | **c.** 45 $N.m^2/C$ | 12. | $\rho = 0.26\ \mu C/m^3$ | 22. | 16 $cm$ outside |
| 3. | **a.** 2.3 $N.m^2/C$ | 13. | $\rho = 2.5\ \mu C/m^3$ | 23. | **b.** 54 N/C |
| 4. | $\phi_E = 7.4\ N.m^2/C$ | 14. | **a.** 7.2 kN/C | 24. | **e.** 1.8 nC/$m^2$ |
| 5. | $\phi_E = 3.53 * 10^5\ N.m^2/C$ | 15. | **b.** 0.76 nC | 25. | **d.** 36 N/C |
| 6. | 1) 0<br>2) $\phi_E = -678\ N.m^2/C$<br>3) $\phi_E = -226\ N.m^2/C$ | 16. | 397 N/C | 26. | **b.** –4.8 $\mu C/m^2$ |
| 7. | **e.** $\pi R^2 E$ | 17. | 40 m/s | 27. | $E = \frac{kQ}{r^2}, E = 0, E = k\frac{2Q}{r^2}$ |
| 8. | **b.** 11 N/C | 18. | $\theta = 10.2°$ | 28. | $F = k\frac{qQ}{r^2}$ toward sphere |
| 9. | **d.** 170 N/C | 19. | **a.** 0.45 kN/C | 29. | **c.** |
| 10. | 7.44 N/C | 20. | **c.** 30 N/C | 30. | **e.** |

# CHAPTER 23:

## ELECTRICAL POTENTIAL

# Chapter 23: Electric Potential (الجهد الكهربائي)

فرق الجهد الكهربائي بين نقطتين ((Electric Potential(V)): هو التغير في طاقة الوضع الكهربائية لكل وحدة شحنة عند انتقالها بين نقطتين في مجال كهربائي. عند وضع شحنة كهربائية في مجال كهربائي خارجي فإن الشحنة والمجال يشكلان نظام وتختزن في النظام طاقة تسمى طاقة الوضع الكهربائي. ففي المجال الكهربائي اصطلح العلماء اللانهاية (∞) أو الأرض طاقة الوضع لها صفر($\boldsymbol{U_{\infty} = 0}$) ولبناء النظام يفرض النقطة في المالانهاية ويتم نقلها الى نقطة ضمن المجال الكهربائي بسرعة ثابتة نؤثر فيها بقوة خارجية تساوي القوة الكهربائية بالمقدار وتعاكسها بالاتجاه وعندئذ تبذل القوة الخارجية (external force) شغلا يختزن في الشحنة الكهربائية على شكل طاقة وضع وتبقى طاقتها الحركية ثابتة.

$U_b = q * V_b$

$U_a = q * V_a$

$\triangle U = U_b - U_a = q * V_b - q * V_a = \mathrm{q}\ (V_b - V_a)$

$$\triangle V_{ba} = \frac{\triangle U}{q_{\circ}} = \frac{U_b - U_a}{q_{\circ}} = V_b - V_a$$

Where:

$\triangle U: (electric\ potential\ energy)$ طاقة الوضع

$\triangle V_{ab}$: Electric Potential.

$q_{\circ}: point\ charge.$

$U_b$: *Potential energy at b.*

$U_a$: *Potential energy at a.*

$U_{\infty} = 0$

عند وضع شحنة حرة في مجال كهربائي فإنها ستنتقل تحت تأثير القوة الكهربائية فقط من النقطة ($A$) الى النقطة ($B$).

إن النظام (الشحنة والمجال) نظام محافظ (Conservation of system) أي ان الطاقة الميكانيكية محفوظة:

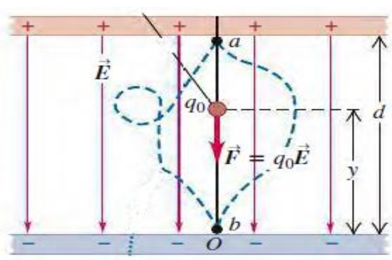
the total mechanical energy (kinetic plus potential) is conserved under these circumstances.

$KE_1 + U_1 = KE_2 + U_2\ , KE: kinetic\ energy$

$KE_2 - KE_1 = U_1 - U_2$

$\triangle KE = - \triangle U_{2\to 1}$

$* KE = \frac{1}{2} m v^2$



تؤدي حركة الشحنات الكهربائية الحرة تحت تأثير القوة الكهربائية فقط الى نقصان طاقة الوضع الكهربائية المختزنة فيها، ويقابل ذلك زيادة مساوية في الطاقة الحركية:

$$W_{a\to b} = -\triangle U$$

$$\triangle V_{ab} = \frac{W_{a\to b}}{q_\circ} = \frac{-\triangle U}{q_\circ}$$

$$W_{a\to b} = -q_\circ\,(V_b - V_a) = q_\circ\,(V_a - V_b) = -\triangle U$$

*Where:*

$W_{a\to b}$ :Work done by a conservative force

❖ **Electric potential due to a point charge:**

إذا كان مصدر المجال الكهربائي شحنة نقطية إذا:

$$V = \frac{kq}{r}$$

**الجهد كمية قياسية: استخدم إشارة الشحنة**

Where:

$r$:Distance from point charge to where potential is measured

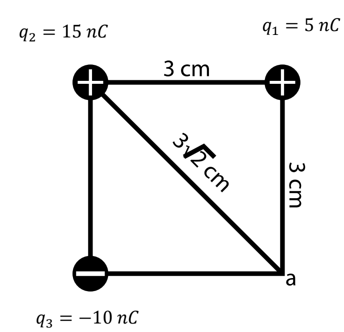
*اتجاه المجال الكهربائي يكون دائما باتجاه تناقص الجهد الكهربائي.

❖ Electric potential due to a collection of point charge

الجهد الكهربائي عند نقطة تقع في مجال شحنات نقطية:

$$V_{tot} = k * \left(\frac{q_1}{r_1} + \frac{q_2}{r_2} + \frac{q_3}{r_3}\dots\right) = k * \sum_i \frac{q_i}{r_i}$$

Ex: in the figure shown, find the electric potential (V) at point (a).




Solution:

$$V_1 = k\frac{q_1}{r_1} \Rightarrow V_1 = \frac{9*10^9*5*10^{-9}}{3*10^{-2}} = 1500\ volt$$

$$V_2 = k\frac{q_2}{r_2} \Rightarrow V_1 = \frac{9*10^9*15*10^{-9}}{3\sqrt{2}*10^{-2}} = \frac{4500}{\sqrt{2}}volt$$

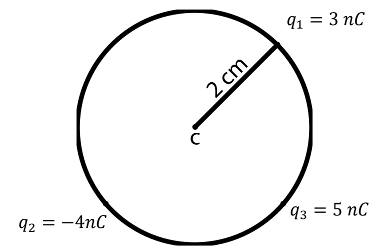
$$V_3 = k\frac{q_3}{r_3} \Rightarrow V_1 = \frac{9*10^9*-10*10^{-9}}{3*10^{-2}} = -3000\ volt$$

$$V_{tot} = V_1 + V_2 + V_3 \Rightarrow V_{tot} = 1500 + \frac{4500}{\sqrt{2}} - 3000$$

$$V_{tot} = 1681.98\ volt$$

Ex: in figure shown, find:

1) Electric potential (V).
2) Electric potential energy (U) for $q = 1\ nC$ .
3) work done to move $q = 1\ nC$ from $\infty$ to center.




Solution:

1) $V_c = V_1 + V_2 + V_3$

$$V_c = k\frac{q_1}{r_1} + k\frac{q_2}{r_2} + k\frac{q_3}{r_3}$$

$$V_c = \frac{k}{r}(q_1 + q_2 + q_3) \Rightarrow V_c = \frac{9*10^9}{2*10^{-2}}(3 - 4 + 5) * 10^{-9}$$

$$V_c = 18*10^2\ volt$$

2) $U_c = q.V_c \Rightarrow U_c = 1 * 10^{-9} * 18 * 10^2$

$$U_c = 18 * 10^{-7}\ Jol$$

Electric potential of $\infty$ is $V_\infty = 0$

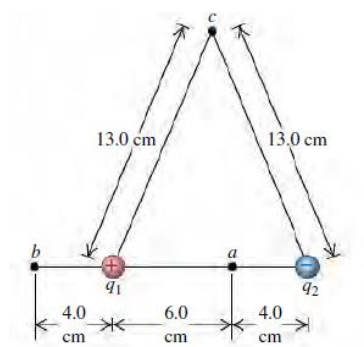
3) $W_{\infty\to c} = \triangle U_{\infty\to c} = q\ \triangle V_{\infty\to c}\ , \triangle V_{\infty\to c} = (V_c - V_\infty)$

$$W_{\infty\to c} = 1 * 10^{-9} * (18 * 10^2 - 0)$$

$$W_{\infty\to c} = 18 * 10^{-7}\ Jol$$

Ex: An electric dipole consists of point charges $q_1 = +12\ nC$ and $q_2 = -12\ nC$ placed $10.0\ cm$ apart as shown. Compute the electric potentials at points a, b, and c.

$$V_a = k * \left(\frac{q_1}{r_1} + \frac{q_2}{r_2}\right) = 9 * 10^9 * \left(\frac{+12*10^{-9}}{6*10^{-2}} + \frac{-12*10^{-9}}{4*10^{-2}}\right)$$




$$\boxed{V_a = -900v}$$

$$V_a = k * \left(\frac{q_1}{r_1} + \frac{q_2}{r_2}\right) = 9 * 10^9 * \left(\frac{+12*10^{-9}}{4*10^{-2}} + \frac{-12*10^{-9}}{14*10^{-2}}\right)$$

$$\boxed{V_b = 1930v}$$

$$\boxed{V_c = 0}$$

**The electric potential energy of tow point charges:**

لتشكيل نظام مكون من شحنتين موجبتين $(q_1،q_2)$ بعيدتين جدا عن بعضهما، فإنهما تنقلان من اللانهائية الى منطقة يكون البعد بينهما (r).

إن نقل الشحنة الأولى $(q_1)$ لا يتطلب بذل شغل لأنها منقولة إلى منطقة لا يوجد فيها مجال كهربائي أما نقل شحنة ثانية $(q_2)$ من المالانهاية إلى نقطة على بعد مسافة (r) من الشحنة الأولى $(q_1)$ فيتطلب التأثير بقوة خارجية تبذل شغلا:

$$U = \frac{kq_1\, q_2}{r_{12}}$$

Where:

$U$: Electric potential energy of two point charges.
$r_{12}$: Distance between two charges.

Ex: A positron (the electron's antiparticle) has mass 9.11 * $10^{-31}$kg and charge($q_0$ = +e = +1.60 * $10^{-19}$ C). Suppose a positron moves in the vicinity of an a (alpha) particle, which has charge (q = +2e C) and mass (6.64 * $10^{-27}$)kg. The a particle's mass is more than 7000 times that of the positron, so we assume that the a particle remains at rest. When the positron is (1* $10^{-10}$m) from the a particle, it is moving directly away from the a particle at (3 * $10^6$ m/s).
(a) What is the positron's speed when the particles are (2* $10^{-10}$ m) apart?
(b) What is the positron's speed when it is very far from the a particle?

Solution: $q_0$ = +1.60 * $10^{-19}c$    q= 3.20 * $10^{-19}c$    $r_1 = 1 * 10^{-10}$ m    $v_1 = 3 * 10^6$ m/s
a)

$$KE_1 + U_1 = KE_2 + U_2$$

$$U_1 = \frac{kq_0 q}{r_1} = \frac{(9 * 10^9) * (1.60 * 10^{-19}) * (3.20 * 10^{-19})}{1 * 10^{-10}} = 4.61 * 10^{-18} J$$

$$U_2 = \frac{kq_0 q}{r_1} = \frac{(9 * 10^9) * (1.60 * 10^{-19}) * (3.20 * 10^{-19})}{2 * 10^{-10}} = 2.3 * 10^{-18} J$$

$$KE_1 = \frac{1}{2} m {v_1}^2 = \frac{1}{2} * (9.11 * 10^{-31}) * (3 * 10^6)^2 = 4.1 * 10^{-18} J$$

$$KE_2 = U_1 - U_2 + KE_1 = 4.61 * 10^{-18} - 2.3 * 10^{-18} + 4.1 * 10^{-18} = 6.41 * 10^{-18} J$$

$$KE_2 = \frac{1}{2} m {v_2}^2$$

$$v_2 = \sqrt{\frac{2*6.41*10^{-18}}{9.11 * 10^{-31}}} = 3.8 * 10^6 \text{m/s}$$

b)
r = $r_3 \to \infty$
$U_3 = 0$

$$KE_1 + U_1 = KE_2 + U_3$$

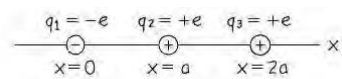
$$KE_2 = KE_1 + U_1 = 4.61 * 10^{-18} + 4.1 * 10^{-18} = 8.71 * 10^{-18} j$$

$$v_3 = \sqrt{\frac{2 * 8.71 * 10^{-18}}{9.11 * 10^{-31}}} = 4.4 * 10^6 m/s$$

Electric Potential Energy with several Point charges

$$U = k * q_0 * \left(\frac{q_1}{r_{10}} + \frac{q_2}{r_{20}} + \frac{q_3}{r_{30}} \dots\right) = k * q_0 * \sum_i \frac{q_i}{r_i}$$

Ex: Two point charges are located on the x-axis, q1 = -e at x = 0 and q2 = +e at x = 1m. (a) Find the work that must be done by an external force to bring a third point charge q3 = +e from infinity to x = 2m.
Solution: q1 = -e q2 = +e q3 = +e




$$U = k * q_3 * \left(\frac{q_1}{r_{13}} + \frac{q_2}{r_{23}}\right) = (9 * 10^9) * 1.6 * 10^{-19} * \left(\frac{-1.6 * 10^{-19}}{2} + \frac{1.6 * 10^{-19}}{1}\right)$$

Finding electric potential from electric field:

$$W_{a \to b} = \int_a^b \vec{F} . \vec{dl} = \int_a^b q_\circ * \vec{E} . \vec{dl}$$

$$(V_a - V_b) = \frac{W_{a \to b}}{q_\circ} = \frac{\int_a^b q_\circ * \vec{E} . \vec{dl}}{q_\circ}$$

$$V_{ba} = -V_{ab} = -(V_a - V_b) = -\int_a^b \vec{E} . \vec{dl} = -\int_a^b \mathrm{E} * \mathrm{dl} * \cos(\phi) = -E * d * \cos(\phi)$$

Where:

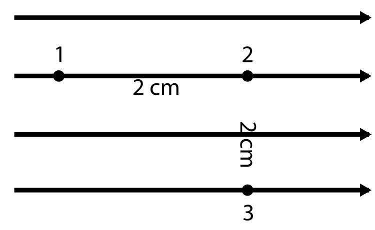
$V_{ab}$: Electric potential difference.
E: Electric field magnitude
$\int_a^b$ dl : Integral along path from $a$ to $b$(المسافة)

$\phi$: Angle between $\vec{E}$ and $\vec{dl}$

## {Done by: Omar Mohammad}

*يعني إذا أعطاك المجال الكهربائي كاقتران وطلب منك الجهد الكهربي كامل المجال الكهربائي.

* وحدة المجال الكهربائي: $1\,\frac{newton}{coulomb} = 1\,\frac{volt}{meter}$ $(E = \frac{V_{ba}}{d})$



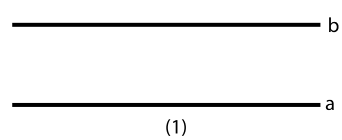

Ex: have $q = 5\ nC$ moves from (1) to (2) then moves from (2) to (3) in uniform $\vec{E}$=500*$10^3\ N/C$ , find $\triangle V_{12}$& $\triangle V_{23}$ .

Solution:

$\triangle V_{12} = E.d\ .\ cos\theta \Rightarrow \triangle V_{12} =\ 500*10^3 * 2 * 10^{-2} * cos0°$
$\triangle V_{12} = 10*10^3\ volt$

$\triangle V_{23} = E.d\ .\ cos\theta = 500 * 10^3 * 2 * 10^{-2} * cos90°$
$\triangle V_{23} = 0$

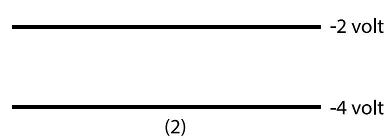
Note:
*all point line from (1) to (2) have same V.
*V from (1) to (2) is positive, then $V_1 > V_2$.
*when we move from (+) to (-) charge the V is decreasing.
*direction of $\vec{E}$ from big V to small V.




Ex: if $V_a > V_b$, find direction of $\vec{E}$ for figure (1) & (2).

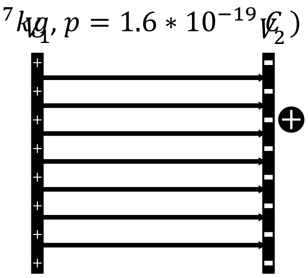
Solution:

(1): from (a) to (b)…( $\hat{j}$)




(2): from (-2) to (-4)… (-$\hat{j}$)

Ex: in figure shown velocity of proton = 5$* 10^6 m/s$ ($mass_{proton} = 1.67 * 10^{-27} kg, p = 1.6 * 10^{-19} C$ )
*when proton enter field its velocity was = 0 and after it became 5$* 10^6 m/s$ .




Find $\triangle V$ for field.

Solution:

$\triangle KE = -\triangle U_{2\to1}$ , $\triangle U_{1\to2} = -\triangle U_{2\to1}$

$\triangle KE = \triangle U_{1\to2} \Rightarrow\ KE_2 - KE_1 = q(\triangle V)$

$\frac{1}{2}m{v_2}^2 - \frac{1}{2}m{v_1}^2 = q(\triangle V) \Rightarrow \frac{1}{2}m({v_2}^2 - {v_1}^2) = q(\triangle V)$

$\frac{1}{2} * 1.67 * 10^{-27} * ((5 * 10^6)^2 - 0) = 1.6 * 10^{-19} * \triangle V$

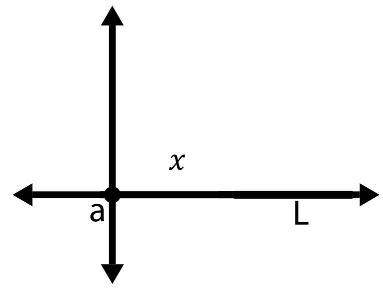
$\triangle V = 130.468 * 10^3\ volt\ , \triangle V = V_1 - V_2$

**Electric potential due to charge distribution (الجهد الكهربائي لتوزيع من الشحنات):**

$\triangle V = -\int E.dl$

$Q = \int \lambda.dl$ (بعد واحد مثل خط)

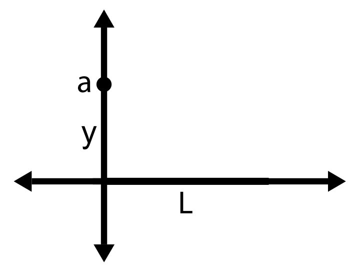
$Q = \int \sigma.ds$(على مساحة)




1) rod:

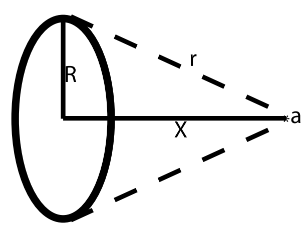
a)

$V_a = k\lambda \ln\left(\frac{x+l}{x}\right)$




b)

$V_a = k\lambda \ln\left(\frac{\sqrt{l^2+y^2}+l}{y}\right)$



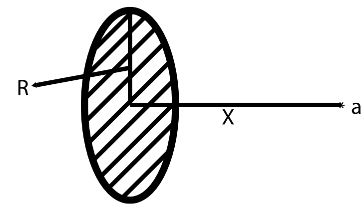

2) ring:

$V_a = \frac{kQ}{R}$

$Q = \lambda(2\pi R)$

*Note: there is V in center.

3)disk:

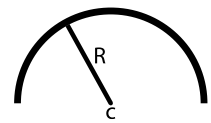



$V_a = 2\pi\sigma k\left[\sqrt{x^2 + R^2} - x\right]$

$Q = \sigma(\pi R^2)$

$\pi$ in rad ($\pi = 3.14$ or $22/7$)

4) semi-circle:




$V_c = k\lambda\theta$

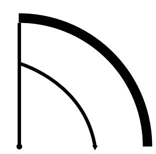
where:

$\theta$ in rad.

$\theta \text{ in rad} = \theta * \frac{\pi}{180}$ ($\pi = 3.14$ or $22/7$)

ex: $\theta = 90°$

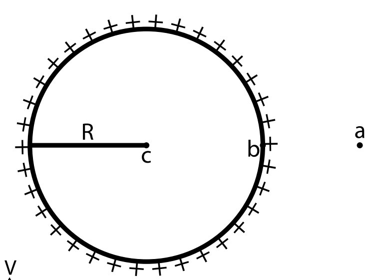
$\theta \text{ in rad} = \theta . \frac{\pi}{180} = 90 * \frac{\pi}{180} = \frac{\pi}{2}$



$\theta = 90° = \frac{\pi}{2} rad$

5)Electric potential due to sphere:

1) conducting sphere:




$\triangle V = -\int E.dl$

$V_\infty$ is the reference.

a) outside r>R:

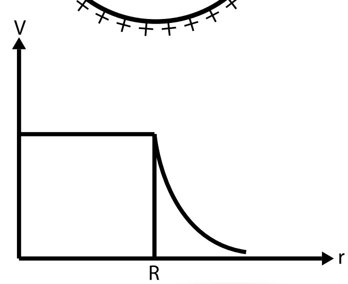
$V_a = k\frac{q}{r}$

b) on sphere:

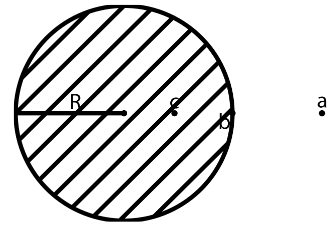
$V_b = k\frac{q}{R}$

c) inside sphere:

$V_c = k\frac{q}{R}$ , $\triangle V = 0 \Rightarrow$ then $V_c = V_b$




*potential inside sphere is equal to on sphere because $\triangle V = 0$




2) non-conducting sphere:

$\triangle V = -\int E.dl$

$V_\infty$ is the reference.

a) outside r>R:

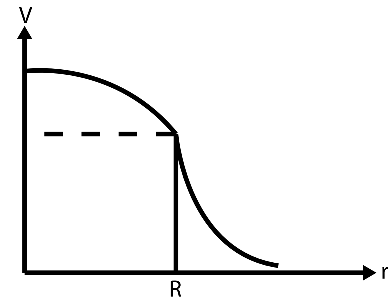
$V_a = k\frac{q}{r}$

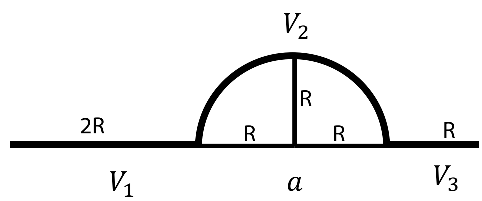
b) on sphere:

$V_b = k\frac{q}{R}$

c) inside sphere:

$V_d = \frac{kq}{2R}\left(3 - \frac{r^2}{R^2}\right)$




Ex: in figure shown, find V at (a).

Solution:

$$V_a = V_1 + V_2 + V_3$$
$$V_1 = k\lambda \ln\left(\frac{x+l}{x}\right) \Rightarrow V_1 = k\lambda \ln\left(\frac{R+2R}{R}\right) \Rightarrow V_1 = k\lambda \ln\left(\frac{3R}{R}\right)$$
$$V_1 = k\lambda \ln(3)$$

$$V_2 = k\lambda\theta \Rightarrow V_2 = k\lambda\pi$$
$$V_2 = k\lambda(3.14)$$

$$V_1 = k\lambda \ln\left(\frac{x+l}{x}\right) \Rightarrow V_1 = k\lambda \ln\left(\frac{R+R}{R}\right) \Rightarrow V_1 = k\lambda \ln\left(\frac{2R}{R}\right)$$
$$V_1 = k\lambda \ln(2)$$

* $\lambda$ is same because same rod.

$$V_a = k\lambda \ln(3) + k\lambda(3.14) + k\lambda \ln(2)$$

$$V_a = k\lambda(\ln(3) + 3.14 + \ln(2))$$

$$V_a = k\lambda(\ln(6) + 3.14)$$

**Electric field calculations from potential:**

إذا أعطاك الجهد الكهربائي وطلب منك المجال الكهربي أشتق الجهد الكهربائي.

*$V$ as a function.*

$$V = -\int E.dl$$

$$E = -\nabla V$$

$$E = -\frac{dV}{dx}\hat{i} - \frac{dV}{dy}\hat{j} - \frac{dV}{dz}\hat{k}$$

Ex: in an area $V = 2x^2y + 2y^2z$ , find $E$ .

Solution:

$E = -\nabla V$

$E = -\frac{dV}{dx}\hat{i} - \frac{dV}{dy}\hat{j} - \frac{dV}{dz}\hat{k}$

$\frac{dV}{dx} = 4xy\ \hat{i}\ , \frac{dV}{dy} = (2x^2 + 4yz)\,\hat{j}, \frac{dV}{dz} = 2y^2\ \hat{k}$

$E = -4xy\ \hat{i} - (2x^2 + 4yz)\,\hat{j} - 2y^2\ \hat{k}$

Ex: $E = 6x^2y\ \hat{i} + 9y^2z\,\hat{j} - 4zx\ \hat{k}, V_{(0,0,0)} = 6$

Find $V$ ?

Solution:

$V = -\int E.dl$

$V = V_x + V_y + V_z$

$V_x = -\int E.dx \Rightarrow\ V_x = -\int (6x^2y\,).dx \Rightarrow\ V_x =\ -(2x^3y + c_1)$

$V_y = -\int E.dy \Rightarrow\ V_y = -\int (9y^2z\,).dy \Rightarrow\ V_y =\ -(3y^3z + c_2)$

$V_z = -\int E.dz \Rightarrow\ V_z = -\int (4zx\,).dz \Rightarrow\ V_z =\ -(2z^2x + c_3)$

$V = -(2x^3y + c_1 + 3y^3z + c_2 + 2z^2x + c_3)$

$V = -(2x^3y + 3y^3z + 2z^2x + c), c = c_1 + c_2 + c_3$

$V_{(0,0,0)} = -(0 + c) = 6 \Rightarrow c = -6$

$V = -(2x^3y + 3y^3z + 2z^2x - 6)$

أهم القوانين:

$electric\ potential\ energy$

$$\triangle V_{ba} = \frac{\triangle U}{q_\circ} = \frac{U_b - U_a}{q_\circ} = V_b - V_a$$

$$W_{a \to b} = -q_\circ (V_b - V_a) = q_\circ (V_a - V_b) = - \triangle U$$

**Electric potential due to a point charge:**

$$V = \frac{kq}{r}$$

**Electric potential due to a collection of point charge**

$$V_{tot} = k * \left(\frac{q_1}{r_1} + \frac{q_2}{r_2} + \frac{q_3}{r_3} \dots.\right) = k * \sum_i \frac{q_i}{r_i}$$

**The electric potential energy of tow point charges:**

$$U = \frac{kq_1\, q_2}{r_{12}}$$

**Finding electric potential from electric field:**

$$V_{ba} = -V_{ab} = -(V_a - V_b) = -\int_a^b \vec{E} \,.\, \vec{dl} = -\int_a^b \mathrm{E} * \mathrm{dl} * \cos(\phi) = E * d * \cos(\phi)$$

**Electric potential due to charge distribution (الجهد الكهربائي لتوزيع من الشحنات):**

$$\triangle V = -\int E.dl$$

$Q = \int \lambda.dl$ (بعد واحد مثل خط)

$Q = \int \sigma.ds$(على مساحة)

# Problems

## Book & more

1-A particle (charge = 50 $\mu$C) moves in a region where the only force on it is an electric force. As the particle moves 25 cm from point A to point B, its kinetic energy increases by 1.5 mJ. Determine the electric potential difference, $V_B - V_A$.

**a.** –50 V **b.** –40 V **c.** –30 V **d.** –60 V **e.** +15 V

$\Delta K = -q(V_B - V_A)$

$1.5 * 10^{-3} = -50 * 10^{-6}(V_B - V_A)$

$(V_B - V_A) = \frac{1.5*10^{-3}}{-50*10^{-6}} = -30V$

2- A particle (charge = +2.0 mC) moving in a region where only electric forces act on it has a kinetic energy of 5.0 J at point A. The particle subsequently passes through point B which has an electric potential of +1.5 kV relative to point A. Determine the kinetic energy of the particle as it moves through point B.

**a.** 3.0 J **b.** 2.0 J **c.** 5.0 J **d.** 8.0 J **e.** 10.0 J

3- A proton (mass = 1.67 $*10^{-27}$ kg, charge = 1.60 $*10^{-19}$ C) moves from point A to point B under the influence of an electrostatic force only. At point A the proton moves with a speed of 60 km/s. At point B the speed of the proton is 80 km/s. Determine the potential difference *V*B – *V*A.

**a.** +15 V **b.** –20 V **c.** –33 V **d.** +33 V **e.** –15 V

$(k_B - k_A) = -q*(V_B - V_A)$

$0.5*m*(v_B{}^2 - v_A{}^2) = -q*(V_B - V_A)$

$0.5*1.67*10^{-27}((80 * 10^3)^2 - (60 * 10^3)^2) = -1.6*10^{-19}(V_B - V_A)$

$(V_B - V_A) = -15V$

4-A point charge $q1$ is held stationary at the origin. A second charge $q2$ is placed at point $a$, and the electric potential energy of the pair of charges is +5.4 * $10^{-8}$ J. When the second charge is moved to point $b$, the electric force on the charge does -1.9 * $10^{-8}$ J of work. What is the electric potential energy of the pair of charges when the second charge is at point $b$?

Answer: 7.3 * $10^{-8}$

$\Delta K = -\Delta U$

$(K_b - K_a) = -1.9*10^{-8}$

$(U_b - U_a) = 1.9*10^{-8}$

$(U_O - U_a) = 5.4*10^{-8}$

$(U_O - U_a) + (U_O - U_a) = 7.3 * 10^{-8}$

5-Two protons, starting several meters apart, are aimed directly at each other with speeds of $2.00 * 10^5$ m/s, measured relative to the earth. Find the maximum electric force that these protons will exert on each other.

Answer: …………

6- A particle ($m$ = 2.0 $\mu$g, $q$ = –5.0 nC) has a speed of 30 m/s at point A and moves (with only electric forces acting on it) to point B where its speed is 80 m/s. Determine the electric potential difference $V$A – $V$B.

**a.** –2.2 MV **b.** +1.1 MV **c.** –1.1 MV **d.** +2.2 MV **e.** 1.3 MV

$(K_A - K_B) = -q(V_A - V_B)$

0.5*2*$10^{-6}$*$(30^2 - 80^2)$= $5 * 10^{-9}$*$(V_A - V_B)$

$(V_{A-}V_B)$ = –1.1 MV

7- Points A [at (3, 6) m] and B [at (8, –3) m] are in a region where the electric field is uniform and given by $E$ = 12**i** N/C. What is the electric potential difference $V$A – $V$B?

**a.** +60 V **b.** –60 V **c.** +80 V **d.** –80 V **e.** +50 V

V= $-\int Ei\, dx - \int Ej\, dy$
$V = -12x$
$V_A = -36\ v$
$V_B = -96v$
$(V_A - V_B)$= $60v$

8- Several charges about point P produce an electric potential of 6.0 kV (relative to zero at infinity) and an electric field of 36**i** N/C at point P. Determine the work required of an external agent to move a 3.0-$\mu$C charge from infinity to point P (without any net change in the kinetic energy of the particle) along the $x$ axis.

**a.** 21 mJ **b.** 18 mJ **c.** 24 mJ **d.** 27 mJ **e.** 12 mJ

9-Three-point charges, which initially are infinitely far apart, are placed at the corners of an equilateral triangle with sides $d$. Two of the point charges are identical and have charge $q$. If zero net-work is required to place the three charges at the corners of the triangle, what must the value of the third charge be?

Answer: …………

10- A particle with charge +4.20 nC is in a uniform electric field ***E*** directed to the left. The charge is released from rest and moves to the left; after it has moved 6.00 cm, its kinetic energy is $+2.20 * 10^{-6}$ J. What is the potential of the starting point with respect to the end point?

Answer: …………

11- Identical 2.0-$\mu$C charges are located on the vertices of a square with sides that are 2.0 m in length. Determine the electric potential (relative to zero at infinity) at the center of the square.

**a.** 38 kV **b.** 51 kV **c.** 76 kV **d.** 64 kV **e.** 13 kV

v=$\frac{kq}{r}$
r=$\sqrt{1+1}$

v=$\frac{9*10^{9}*2*10^{-6}}{\sqrt{2}}$ =12727.9
$V_{at\ center} = 4 * v = \ 51\ kv$

12- Identical 4.0-$\mu$C charges are placed on the $y$ axis at $y = \pm 4.0$ m. Point A is on the $x$ axis at $x =$ +3.0 m. Determine the electric potential of point A (relative to zero at the origin).

**a.** –4.5 kV **b.** –2.7 kV **c.** –1.8 kV **d.** –3.6 kV **e.** –14 kV

13- A particle (charge = $q$) is released from rest when it is a distance of 3.0 m from a point charge $Q$, which is held at a fixed position. If $Q$ = 50 $\mu$C and $q$ = –36 $\mu$C, what is the kinetic energy of the particle after it has traveled 1.0 m?

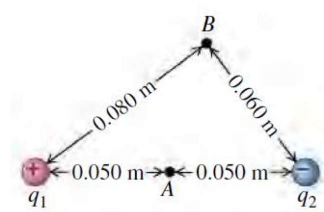
**a.** 3.3 J **b.** 3.0 J **c.** 2.7 J **d.** 3.6 J **e.** 14 J

$\Delta K = -q(\frac{kQ}{r_2} - \frac{kQ}{r_3})$

$\Delta K = 36 * 10^{-6}(75000) = 2.7\ J$

14- Two-point charges $q1$ = +2.40 nC and $q2$ = -6.50 nC are 0.100 m apart. Point $A$ is midway between them; point $B$ is 0.080 m from $q1$ and 0.060 m from $q2$ in figure. Take the electric potential to be zero at infinity. Find the potential at point $A$.

Answer: …………




$$V_{Total} = \frac{kq_1}{r} + \frac{kq_2}{r}$$

$$V_{Total} = -737.1$$

15- A total electric charge of 3.50 nC is distributed uniformly over the surface of a metal sphere with a radius of 24.0 cm. If the potential is zero at a point at infinity, find the value of the potential at the distance 48.0 cm from the center of the sphere.

Answer: 65.6V

$V_{out}=\frac{kq}{r}=\frac{9*10^9*3.5*10^{-9}}{48*10^{-2}}$=65.6V

16- A particle (charge = 5.0 $\mu$C) is released from rest at a point $x$ = 10 cm. If a 5.0-$\mu$C charge is held fixed at the origin, what is the kinetic energy of the particle after it has moved 90 cm?

**a.** 1.6 J **b.** 2.0 J **c.** 2.4 J **d.** 1.2 J **e.** 1.8 J

17- A particle ($q$ = +5.0 $\mu$C) is released from rest when it is 2.0 m from a charged particle which is held at rest. After the positively charged particle has moved 1.0 m toward the fixed particle, it has a kinetic energy of 50 mJ. What is the charge on the fixed particle?

**a.** –2.2 $\mu$C **b.** +6.7 $\mu$C **c.** –2.7 $\mu$C **d.** +8.0 $\mu$C **e.** –1.1 $\mu$C

18- Through what potential difference must an electron (starting from rest) be accelerated if it is to achieve a speed of 3.0 $*10^7$ m/s?

**a.** 5.8 kV **b.** 2.6 kV **c.** 7.1 kV **d.** 8.6 kV **e.** 5.1 Kv

$\Delta k = -q * \Delta V$

$0.5 * 9.1 * 10^{-31} * (3.0 * 10^7)^2$ =1.6*$10^{-19}$*$\Delta V$

$\Delta V = 2.6Kv$

19-A very long insulating cylinder of charge of radius 2.50 cm carries a uniform linear density of 15.0 nC/m. If you put one probe of a voltmeter at the surface, how far from the surface must the other probe be placed so that the voltmeter reads 175 V?

Answer: …………

20- In a certain region of space the electric potential is given by $V$ = +$Ax^2y$ - $Bxy^2$, where $A$ = 5.00 $V/m^3$ and $B$ = 8.00 $V/m^3$. Calculate the magnitude and direction of the electric field at the point in the region that has coordinates $x$ = 2.00 m, $y$ = 0.400 m, and $Z$ = 0.

Answer: …………

$E = -\frac{dv}{dx} - \frac{dv}{dy}$

21- A charge $Q$ is uniformly distributed along the $x$ axis from $x = a$ to $x = b$. If $Q = 45$ nC, $a = -3.0$ m, and $b = 2.0$ m, what is the electric potential (relative to zero at infinity) at the point, $x = 8.0$ m, on the $x$ axis?

**a.** 71 V **b.** 60 V **c.** 49 V **d.** 82 V **e.** 150 V

$V_x = K * \left({}^{Q}/_{L}\right) * (Ln((d + l)/d))$

$V_x = 9 * 10^9 \left({}^{45 * 10^{-9}}/_{5}\right) * (Ln((6 + 5)/6))$=49 V

22- A charge of 20 nC is distributed uniformly along the $x$ axis from $x = -2$ m to $x = +2.0$ m. What is the electric potential (relative to zero at infinity) at the point $x = 5.0$ m on the $x$ axis?

**a.** 57 V **b.** 48 V **c.** 38 V **d.** 67 V **e.** 100 V

23- A nonuniform linear charge distribution given by $\lambda$ (x) = $bx$, where $b$ is a constant, is distributed along the $x$ axis from $x = 0$ to $x = +L$. If $b = 40$ nC/m2 and $L = 0.20$ m, what is the electric potential (relative to a potential of zero at infinity) at the point, $y = 2L$, on the $y$ axis?

**a.** 19 V **b.** 17 V **c.** 21 V **d.** 23 V **e.** 14 V

24- A positive point charge $q1 = +5.00 * 10^{-4}$C is held at a fixed position. A small object with mass $4.00 * 10^{-3}$ kg and charge $q2 = -3.00 * 10^{-4}$ C is projected directly at $q1$. Ignore gravity. When $q2$ is 0.400 m away, its speed is 800 m/s. What is its speed when it is 0.200 m from $q1$?

Answer: …………

25- A small sphere with mass 1.50 g hangs by a thread between two very large parallel vertical plates 5.00 cm apart in figure. The plates are insulating and have uniform surface charge densities $+\sigma$ and - $\sigma$. The charge on the sphere is $q = 8.90 * 10^{-6}$ C. What potential difference between the plates will cause the thread to assume an angle of 30.0° with the vertical?

Answer: …………

26- A charge of 4.0 nC is distributed uniformly along the $x$ axis from $x = +4$ m to $x = +6$ m. Which of the following integrals is correct for the electric potential (relative to zero at infinity) at the origin?

**a.** $\int_4^6 \frac{18dx}{4-x}$ **b.** $\int_4^6 \frac{36dx}{x}$ **c.** $\int_4^6 \frac{18dx}{x}$ **d.** $\int_4^6 \frac{36dx}{6-x}$ **e.** $\int_4^6 \frac{36dx}{4+x}$

$V = k * \int_4^6 \frac{\lambda}{r} dx$

$V = 9 * 10^9 * \int_4^6 \frac{4 * 10^{-9}}{x * 2} dx = \int_4^6 \frac{18}{x} dx$

27-A charge of 18 nC is uniformly distributed along the $y$ axis from $y = 3$ m to $y = 5$ m. Which of the following integrals is correct for the electric potential (relative to zero at infinity) at the point $x = +2$ m on the $x$ axis?

**a.** $\int_3^5 \frac{81dy}{(y^2+4)^{1/2}}$ **b.** $\int_3^5 \frac{162dy}{(y^2+4)^{1/2}}$ **c.** $\int_3^5 \frac{81dy}{y^2+4}$ **d.** $\int_3^5 \frac{162dy}{y^2+4}$ **e.** $\int_3^5 \frac{81dy}{y}$

28-The electric field in a region of space is given by $E_x = (3.0x)$ N/C, $E_y = E_z = 0$, where $x$ is in m. Points A and B are on the $x$ axis at $x_A = 3.0$ m and $x_B = 5.0$ m. Determine the potential difference $V_B - V_A$.

**a.** –24 V **b.** +24 V **c.** –18 V **d.** +30 V **e.** –6.0 V

29-When a charged particle is moved along an electric field line,

**a.** the electric field does not work on the charge.
**b.** the electrical potential energy of the charge does not change.
**c.** the electrical potential energy of the charge undergoes the maximum change in magnitude.
**d.** the voltage changes, but there is no change in electrical potential energy.
**e.** the electrical potential energy undergoes the maximum change, but there is no change in voltage.

30- The electric potential inside a charged solid spherical conductor in equilibrium:

**a.** is always zero.
**b.** is constant and equal to its value at the surface.
**c.** decreases from its value at the surface to a value of zero at the center.
**d.** increases from its value at the surface to a value at the center that is a multiple of the potential at the surface.
**e.** is equal to the charge passing through the surface per unit time divided by the resistance.

{Done by: Omar Mohammad}

| | | | | | |
|---|---|---|---|---|---|
| 1. | **c.** –30 V | 11. | **b.** 51 kV | 21. | **c.** 49 V |
| 2. | **b.** 2.0 J | 12. | **d.** –3.6 kV | 22. | **c.** 38 V |
| 3. | **e.** –15 V | 13. | **c.** 2.7 J | 23. | **b.** 17 V |
| 4. | $+7.3 * 10^{-8}\ J$ | 14. | $V_A = -737.1\ V$ | 24. | $v = 1.52\ km/s$ |
| 5. | $0.194 * 10^{-4} N$ | 15. | $V = 65.6\ V$ | 25. | $V = 47.75 V$ |
| 6. | **c.** –1.1 kV | 16. | **b.** 2.0 J | 26. | **c.** $\int_4^6 \frac{18dx}{x}$ |
| 7. | **a.** +60 V | 17. | **a.** –2.2 $\mu$C | 27. | **a.** $\int_3^5 \frac{81dy}{(y^2+4)^{1/2}}$ |
| 8. | **b.** 18 mJ | 18. | **b.** 2.6 kV | 28. | **a.** –24 V |
| 9. | $q_3 = \frac{-q}{2}$ | 19. | 2.3 cm | 29. | **c.** |
| 10. | 523.80 V | 20. | $E = -6.72\ \hat{i} - 7.2\ \hat{j}\ N/C$ | 30. | **b.** |

اسألني
عن الهندسة

# اسألني عن
# الفيزياء2

إعداد: عمر الحمري

اسألني عن الهندسة

{Done by: Omar Mohammad}

# CHAPTER 24:

## CAPACITANCE & DIELECTRICS

# Chapter 24: Capacitance & Dielectrics (المواسعات)

المواسع (Capacitor): أدى تستخدم لتخزين الطاقة الكهربائية.

يتكون المواسع من موصلين (any two conductors) تفصل بينهما مادة عازلة (an insulator) مثل الهواء أو البلاستيك أو الورق.

The capacitance depends on (يعتمد المواسع على):
1) geometric of capacitor (الأبعاد الهندسية).
2)type of insulator material (نوع المادة العازلة).

Types of capacitors (أنواع المواسعات):
1) parallel plates.
2) cylindrical.
3) spherical.

1) parallel plates capacitor:

يتكون المواسع ذو الصفيحتين المتوازيتين، من صفيحتين موصلتين متوازيتان متساويتان في المساحة، تفصل بينهما طبقة من مادة عازلة.

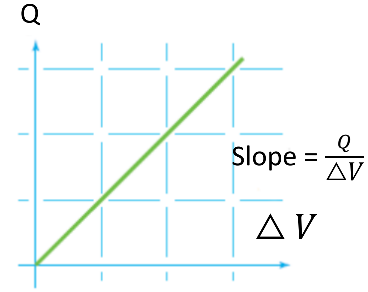
المواسعة الكهربائية: هي النسبة بين كمية الشحنة المختزنة في المواسع وفرق الجهد بين طرفيه (صفيحتيه).

$$C = \frac{Q}{\triangle V}$$

Where:
$C$ : Capacitance of a parallel-plate capacitor in vacuum.
$Q$: Magnitude of charge on each plate.
$\triangle V$: Potential difference between plates.

نسبة الشحنة مقسومة على فرق الجهد على أطراف المواسع (السعة) ثابتة لا تتغير إذا تغيرت الشحنة ($Q$) فإن الجهد يتغير ($\triangle V$).

the ratio of charge to potential difference does not change.




The unit of [c]: farad(F)

1farad(F)=1coulomb(C)/1volt(V)

عند شحن المواسع فإن الشحنات تنتشر على سطحي صفيحتيه، فينشأ في الحيز بين صفيحتي مجال كهربائي فإذا كان البعد بين الصفيحتين صغير جدا فإن المجال الكهربائي يكون منتظما بين صفيحتيه $(E = \frac{\sigma}{\varepsilon_0})$ ويكون فرق الجهد بين الصفيحتين $(\triangle V = E.d)$.

$\triangle V = E.d$ $\quad E = \frac{\sigma}{\varepsilon_0}$ $\quad \sigma = \frac{Q}{A}$ (للمجال المنتظم بين صفيحتين)

$$C = \frac{Q}{\triangle V} = \frac{Q}{E.d} = \frac{Q}{\frac{\sigma}{\varepsilon_0}.d} = \frac{Q * \varepsilon_0}{\frac{Q}{A}.d}$$

$$C = \frac{Q}{\triangle V} = \frac{A * \varepsilon_0}{d}$$

Where:

$A$: Area of each plate
$d$: Distance between plates
$\varepsilon_0$: Electric constant

Ex1: parallel plate capacitor the distance between its plates $d = 1.2\ mm$ and the area of plate

$A = 15 * 10^{-4}\ m^2$ and $\vec{E}$ between plates 3.6 $V/m$, find:

1) capacitance(C).
2) potential difference $(\triangle V)$.
3) the charge $(Q)$.
4) charge density $(\sigma)$.

Solution:

1) $C = \frac{A.\varepsilon_0}{d} \Rightarrow C = \frac{8.85*10^{-12}*15*10^{-4}}{1.2*10^{-3}} \Rightarrow C = 11.06\ pF$

2) $\triangle V = E.d \Rightarrow \triangle V = 3.6*1.2 * 10^{-3}$

$\triangle V = 4.32*10^{-3}\ V$

3) $C = \frac{Q}{\triangle V} \Rightarrow 11.06 * 10^{-12} = \frac{Q}{4.32*10^{-3}}$
$Q = 4.78 * 10^{-14}\ C$

4) $\sigma = \frac{Q}{A} \Rightarrow \sigma = \frac{4.78*10^{-14}}{15*10^{-4}}$

$\sigma = 3.2 * 10^{-11}\ C/m^2$

Ex2: parallel plate capacitor C=$40\mu F$ and connect with battery $\triangle V = 36\,V$, find:

1) The charge ($Q$).

2) The charge ($Q$) if area was doubled.

3) The charge ($Q$) if distance between plates was doubled.

Solution:

1) $C = \frac{Q}{\triangle V} \Rightarrow 40 * 10^{-6} = \frac{Q}{36}$

$Q = 1.44\,mC$

2) from $C = \frac{A.\varepsilon_0}{d}$, $d$ is constant $A$ was doubled

$C' = \frac{A'\varepsilon_0}{d}, A' = 2A$

$C' = \frac{2A\varepsilon_0}{d} \Rightarrow C' = 2C$

$C = \frac{Q}{\triangle V} \Rightarrow Q = C.\triangle V \Rightarrow Q' = C' \triangle V$

$Q' = 2C.\triangle V \Rightarrow Q' = 2Q$

$Q' = 2 * 1.44 * 10^{-3} \Rightarrow Q' = 2.88\,mC$

3) from $C = \frac{A.\varepsilon_0}{d}$, $A$ is constant $d$ was doubled

$C' = \frac{A\varepsilon_0}{d'}, d' = 2d$

$C' = \frac{A\varepsilon_0}{2d} \Rightarrow C' = \frac{1}{2}C$

$C = \frac{Q}{\triangle V} \Rightarrow Q = C.\triangle V \Rightarrow Q' = C' \triangle V$

$Q' = \frac{1}{2}C.\triangle V \Rightarrow Q' = \frac{1}{2}Q$

$Q' = \frac{1}{2} * 1.44 * 10^{-3} \Rightarrow Q' = 0.72\,mC$

❖ energy storage in capacitors and electric field energy:

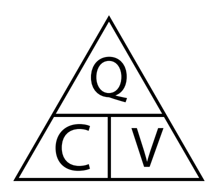
عندما يتصل المواسع مع البطارية فإنهما يشكلان نظاما معزولا، تبذل في البطارية شغلا لنقل الشحنات الى صفيحتي المواسع.

$U = Q.\triangle V \Rightarrow du = dq.\triangle V$

$U = \int dq \;\triangle V \Rightarrow U = \int dq \;\frac{Q}{C}$

$U = \frac{1}{C}\int Q\,dq \Rightarrow U = \frac{1}{C}.\frac{1}{2}.Q^2$

$$U = \frac{1}{2}\frac{Q^2}{C} = \frac{1}{2}CV^2 = \frac{1}{2}QV$$




$C = \frac{Q}{V}$

$V = \frac{Q}{C}$

$Q = CV$

الأحلام هي نقطة البداية لأي نجاح

We connect a capacitor $C_1 = 8.0\ \mathrm{mF}$ to a power supply, charge it to a potential difference $v_0 = 120\ \mathrm{V}$, and disconnect the power supply. Switch S is open.

(a) What is the charge $Q_0$ on $C_1$.

(b) What is the energy stored in $C_1$.

Solution:

a)

$$Q_0 = C_1 * v_0 = 8.0 * 10^{-3} * 120$$

$$Q_0 = 960\ \mu c$$

b)

$$U = \frac{1}{2}\frac{{Q_0}^{2}}{C_1} = \frac{1}{2}\frac{(960 * 10^{-3})^{2}}{8.0 * 10^{-3}}$$

$$U = 0.058\mathrm{J}$$

electric-field energy:

$u = \frac{U}{V}$ , $V: volume$

$u = \frac{U}{A.d} \Rightarrow u = \frac{\frac{1}{2}CV^{2}}{A.d} \Rightarrow u = \frac{\frac{1}{2}\frac{A.\varepsilon_0}{d}V^{2}}{A.d}$

$u = \frac{\varepsilon_0 V^{2}}{2\, d^2} \Rightarrow u = \frac{1}{2}\ \varepsilon_0 E^2 , E = \frac{V}{d}$

Unit of $[u]$: $Jol/m^3$

$$u = \frac{1}{2}\ \varepsilon_0 E^2$$

Where:

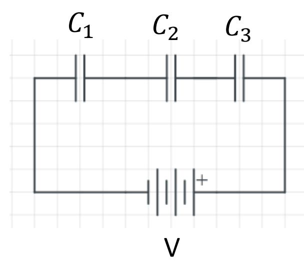
$u$: Electric energy density in a vacuum

$E$: Magnitude of electric field

Combinations of capacitors (توصيل المواسعات):

❖ capacitors in series (التوصيل على التوالي):

في التوصيل على التوالي تكون المواسعات متساوية في الشحنة، بينما الجهد الكلي مساويا لمجموع جهد المواسعات.




$C\ equivalent$:

$$V = V_1 + V_2 + V_3$$

$$\frac{Q}{C} = \frac{Q_1}{C_1} + \frac{Q_2}{C_2} + \frac{Q_3}{C_3}$$

$$\frac{Q}{C} = Q\left(\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}\right)$$

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

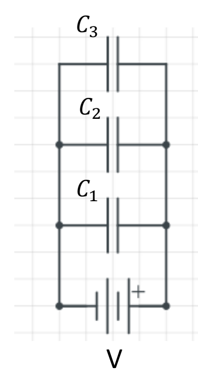
*$C_{eq}$ is smaller than any capacitor in parallel.

حالة خاصة إذا كان عندي مواسعين:

$$C_{eq} = \frac{C_1 * C_2}{C_1 + C_2}$$ (ضربهم على جمعهم)

❖ capacitors in parallel (التوصيل على التوازي):

في التوصيل على التوازي تكون المواسعات متساوية في الجهد، بينما الشحنة الكلي مساويا لمجموع شحنة المواسعات.




$C\ equivalent$:

$$Q = Q_1 + Q_2 + Q_3$$

$$C.V = C_1.V + C_2.V + C_3.V$$

$$C.V = V.(C_1 + C_2 + C_3)$$

$$C_{eq} = C_1 + C_2 + C_3 + \cdots$$

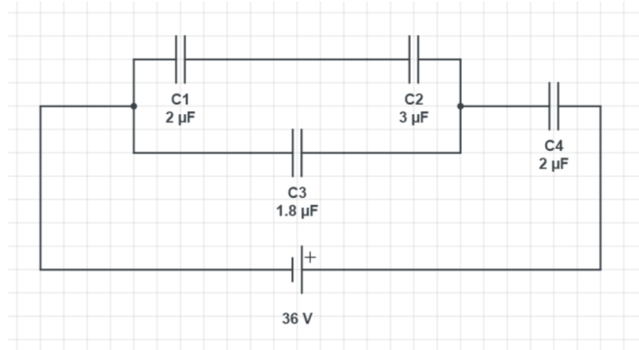
*$C_{eq}$ is grater than any capacitor in parallel

Ex: in figure shown, find:

1) $C_{eq}$.

2) Q for $C_4 = 1.8\mu F$.

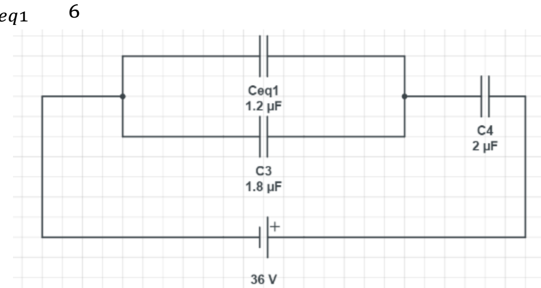
3) $V$ for $C_2 = 3\mu F$.




Solution:

1) $C_1$and $C_2$ is series $\Rightarrow \frac{1}{C_{eq1}} = \frac{1}{C_1} + \frac{1}{C_2} \Rightarrow \frac{1}{C_{eq1}} = \frac{1}{3} + \frac{1}{2} \Rightarrow \frac{1}{C_{eq1}} = \frac{5}{6}$

$C_{eq1} = 1.2\ \mu F.$




$C_{eq1}$ *and* $C_3$ is parallel.

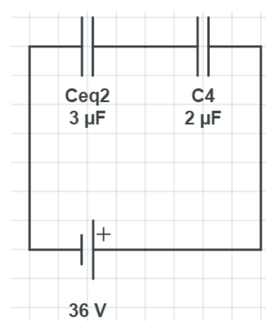
$C_{eq2}$=$C_{eq1} + C_3 \Rightarrow C_{eq2} = 1.2 + 1.8$

$C_{eq2} = 3\ \mu F$

$C_{eq2}$ and $C_4$ is in series.

$\frac{1}{C_{eq}} = \frac{1}{C_{eq2}} + \frac{1}{C_4} \Rightarrow \frac{1}{C_{eq}} = \frac{1}{3} + \frac{1}{2}$

$C_{eq} = 1.2\ \mu F$




2) $C = \frac{Q}{\triangle V} \Rightarrow Q = C.\triangle V \Rightarrow Q = 1.2 * 10^{-6} * 36$

$Q = 43.2\ \mu F$

$*\ Q$ of $C_{eq}$ = $Q$ of $C_{eq2}$ = $Q$ of $C_4$

$C_{eq2} = \frac{Q}{\triangle V} \Rightarrow \triangle V = \frac{Q}{C_{eq2}} \Rightarrow \triangle V = \frac{43.2*10^{-6}}{3*10^{-6}}$

$V_{eq2} = 14.4\ V$

$* V_{eq2} = V_{eq1} = V\ of\ C_3$

$C_3 = \frac{Q_3}{V_3} \Rightarrow Q_3 = C_3.V_3 \Rightarrow Q_3 = 1.8 * 10^{-6} * 14.4$

$Q_3 = 25.92\ \mu C$

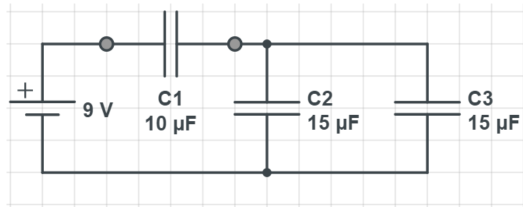
3) $V_{eq1} = 14.4\ V \Rightarrow C_{eq1} = \frac{Q_{eq1}}{V_{eq1}} \Rightarrow Q_{eq1} = C_{eq1}.V_{eq1}$

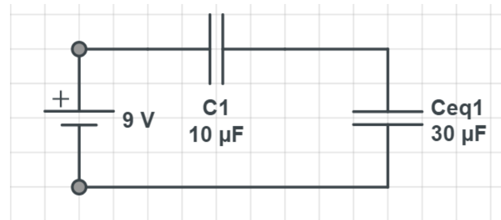
$Q_{eq1} = 1.2 * 10^{-6} * 14.4 \Rightarrow Q_{eq1} = 17.28\ \mu C$

$C_2 = \frac{Q_2}{V_2} \Rightarrow V_2 = \frac{Q_2}{C_2} \Rightarrow V_2 = \frac{17.28*10^{-6}}{3*10^{-6}}$

$V_2 = 5.76\ V$

Ex: in figure shown, find energy in $C_4$ ?




Solution:

$C_2$ *and* $C_3$ is parallel $\Rightarrow\ C_{eq1} = C_2 + C_3$

$C_{eq1} = 15 + 15\ \Rightarrow C_{eq1} = 30\ \mu F$

$C_{eq1}$ and $C_1$ is in series $\Rightarrow \frac{1}{C_{eq2}} = \frac{1}{C_{eq1}} + \frac{1}{C_1}$

$\frac{1}{C_{eq2}} = \frac{1}{30} + \frac{1}{10} \Rightarrow \frac{1}{C_{eq2}} = \frac{4}{30}$

$C_{eq2} = 7.5\ \mu F$

$C_{eq} = \frac{Q_{eq}}{V_{eq}} \Rightarrow Q_{eq} = C_{eq} . V_{eq} \Rightarrow Q_{eq} = 7.5 * 10^{-6} * 9$

$Q_{eq} = 67.5\ \mu C = Q_{eq1} = Q_1$

$C_{eq1} = \frac{Q_{eq1}}{V_{eq1}} \Rightarrow V_{eq1} = \frac{Q_{eq1}}{C_{eq1}} \Rightarrow V_{eq1} = \frac{67.5*10^{-6}}{30*10^{-6}}$

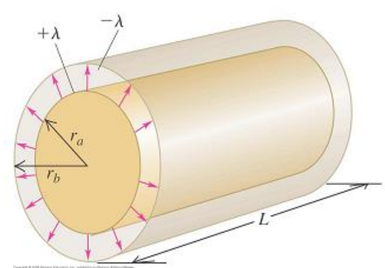
$V_{eq1} = 2.25\ V = V_2 = V_3$

$U_2 = \frac{1}{2} C_2 {V_2}^2 \Rightarrow U_2 = \frac{1}{2} * 15 * 10^{-6} * (2.25)^2$

$U_2 = 38\ \mu J$

2) cylindrical capacitor:

Two cylindrical conductors are separated by insolated.




$C = \frac{Q}{\triangle V}$

$\triangle V = -\int E . dl$

$E = \frac{Q}{2\pi\varepsilon_0 (r) . l}$ , for cylinder

$\triangle V = -\int \frac{Q}{2\pi\varepsilon_0 (r) . l} . dl \Rightarrow \triangle V = -\frac{Q}{2\pi\varepsilon_0 . l} \int \frac{1}{r} . dl , dl = -dr$

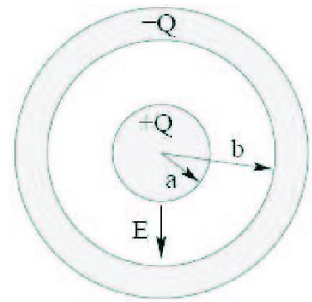
$\triangle V = \frac{Q}{2\pi\varepsilon_0 . l} \int_{r_a}^{r_b} \frac{1}{r} . dr \Rightarrow \triangle V = \frac{Q}{2\pi\varepsilon_0 . l} . \ln\frac{r_b}{r_a}$

$C = \frac{Q}{\frac{Q}{2\pi\varepsilon_0 . l} . \ln\frac{r_b}{r_a}}$

$C = \frac{2\pi\varepsilon_0 . l}{\ln\frac{r_b}{r_a}}$

3) spherical capacitor:

Two spherical conductors are separated by insolated.




$$C = \frac{Q}{\triangle V}$$

$$\triangle V_{b\to a} = V_a - V_b$$

$$V_a = \frac{Q}{4\pi\varepsilon_0 \, (r_a)} \text{ , for conducting sphere}$$

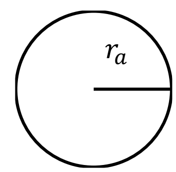
$$V_b = \frac{Q}{4\pi\varepsilon_0 \, (r_b)}$$

$$\triangle V = \frac{Q}{4\pi\varepsilon_0 \, (r_a)} - \frac{Q}{4\pi\varepsilon_0 \, (r_b)} \Rightarrow \triangle V = \frac{Q}{4\pi\varepsilon_0}\left(\frac{1}{r_a} - \frac{1}{r_b}\right)$$

$$C = \frac{Q}{\frac{Q}{4\pi\varepsilon_0}\left(\frac{1}{r_a} - \frac{1}{r_b}\right)}$$

$$C = \frac{4\pi\varepsilon_0}{\left(\frac{1}{r_a} - \frac{1}{r_b}\right)}$$

Special case: one conducting sphere radius of another sphere $r = \infty$




$$C = \frac{4\pi\varepsilon_0}{\left(\frac{1}{r_a} - \frac{1}{\infty}\right)} \Rightarrow C = \frac{4\pi\varepsilon_0}{\frac{1}{r_a}}$$

$$C = 4\pi\varepsilon_0 \, r_a$$

**{Done by: Omar Mohammad}**

## Dielectrics:

عندما يوجد في الحيز بين الصفيحتين مادة عازلة (C) وليس فراغ ($C_0$) فإن سعته ستزداد ($C = \frac{\varepsilon * A}{d}$) والنسبة بينهما يسمى ثابت العزل (Dielectric constant). 

$K = \frac{C}{C_0}$

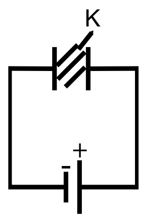
$C > C_0$

$\varepsilon = K\varepsilon_0$

$C = K\frac{\varepsilon_0 A}{d}$

Where:

$K$: dielectrics constant number greater than 1. ($K > 1$:ثابت العزل)




* if there is insolated material and battery is connected (وجود مادة عازلة مع بقاء توصيل البطارية).

$C = K\frac{\varepsilon_0 A}{d}, C_0 = \frac{\varepsilon_0 A}{d} \Rightarrow C = KC_0$

$C > C_0$

$C = \frac{Q}{V}, C_0 = \frac{Q_0}{V_0}$

$V = V_0$, same battery

$C = \frac{KQ_0}{V_0} = kC_0$

*If there is insolated material and remove the battery (وجود مادة عازلة مع فصل البطارية).

$C = K\frac{\varepsilon_0 A}{d}, C_0 = \frac{\varepsilon_0 A}{d} \Rightarrow C = KC_0$

$C > C_0$

$C = \frac{Q}{V}, C_0 = \frac{Q_0}{V_0}$

$Q = Q_0$, same charge

$C = \frac{Q_0}{V_0/K}$

$C = KC_0 , C > C_0$

$\varepsilon = K\varepsilon_0 , \varepsilon > \varepsilon_0$

$Q = KQ_0 , Q > Q_0$

.................................

$E = E_0/K , E < E_0$

$U = U_0/K , U < U_0$

$u = u_0/K , u < u_0$

$V = V_0/K , V < V_0$

*If put different insolated material: (إذا وضع مواد عازلة مختلفة):

* نقسم المواسع لأكثر من مواسع.

* إذا كان على طول المواسع يكون توصيل المواسعات على التوالي.

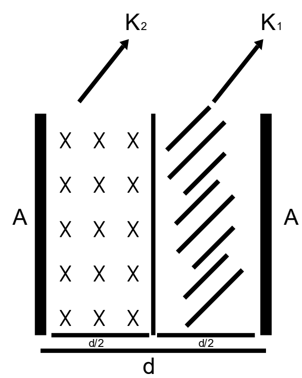
*إذا كان التقسيم على المساحة يكون توصيل المواسعات على التوازي.

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

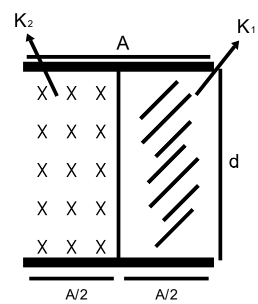
$$\frac{1}{C_{eq}} = \frac{d}{2K_1\varepsilon_0 A} + \frac{d}{2K_2\varepsilon_0 A}$$

$$\frac{1}{C_{eq}} = \frac{d}{2\varepsilon_0 A}(\frac{1}{K_1} + \frac{1}{K_2})$$

$$C_{eq} = \frac{2\varepsilon_0 A}{d} \cdot \frac{K_1K_2}{(K_1+K_2)}$$




in series



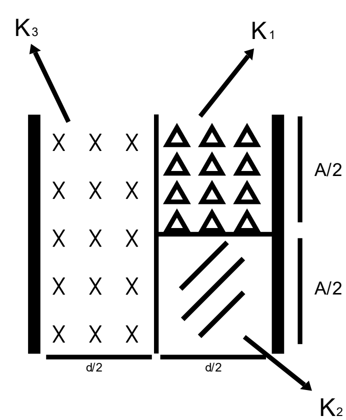

in parallel

$$C_{eq} = C_1 + C_2$$

$$C_{eq} = \frac{K_1\varepsilon_0 A}{d.2} + \frac{K_2\varepsilon_0 A}{d.2}$$

$$C_{eq} = \frac{\varepsilon_0 A}{d.2}(K_1 + K_2)$$

Ex: in figure shown, find C:




Solution:

$C_1$ and $C_2$are in parallel.

$$C_{eq1} = C_1 + C_2$$

$$C_{eq1} = \frac{K_1\varepsilon_0 \frac{A}{2}}{\frac{d}{2}} + \frac{K_2\varepsilon_0 \frac{A}{2}}{\frac{d}{2}}$$

$$C_{eq1} = \frac{\varepsilon_0 A}{d}(K_1 + K_2)$$

$C_{eq1}$ and $C_3$ in series.

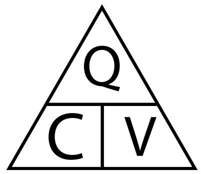
$$\frac{1}{C_{eq}} = \frac{1}{C_{eq1}} + \frac{1}{C_3} \Rightarrow \frac{1}{C_{eq}} = \frac{d}{\varepsilon_0 A(K_1+K_2)} + \frac{d}{2\varepsilon_0 AK_3}$$

$$\frac{1}{C_{eq}} = \frac{d}{\varepsilon_0 A}(\frac{1}{K_1+K_2} + \frac{1}{2K_3}) \Rightarrow C_{eq} = \frac{\varepsilon_0 A}{d}\left(\frac{2K_3(K_1+K_2)}{2K_3+K_1+K_2}\right)$$

أهم القوانين:

**Capacitance**

$$C = \frac{Q}{\triangle V} = \frac{A * \varepsilon_0}{d}$$




$C = \frac{Q}{V}$ $V = \frac{Q}{C}$ $Q = CV$

**energy storage in capacitors and electric field energy:**

$$U = \frac{1}{2}\frac{Q^2}{C} = \frac{1}{2}CV^2 = \frac{1}{2}QV$$

**electric-field energy:**

$$u = \frac{1}{2}\ \varepsilon_0 E^2$$

**cylindrical capacitor:**

**Two cylindrical conductors are separated by insolated.**

$$C = \frac{2\pi\varepsilon_0 . l}{\ln\frac{r_b}{r_a}}$$

**spherical capacitor:**

**Two spherical conductors are separated by insolated.**

$$C = \frac{4\pi\varepsilon_0}{(\frac{1}{r_a} - \frac{1}{r_b})}$$

**Special case: one conducting sphere radius of another sphere $r = \infty$**

$$C = 4\pi\varepsilon_0 r_a$$

**Dielectrics:**

$C = KC_0 , C > C_0$

$\varepsilon = K\varepsilon_0 , \varepsilon > \varepsilon_0$

$Q = KQ_0 , Q > Q_0$

$U = U_0/K , U < U_0$

$u = u_0/K , u < u_0$

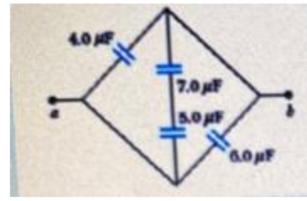
$V = V_0/K , V < V_0$

# Problems

**Book & more**

## أسئلة سنوات محلولة:

Q1) For the circuit shown, the charge stored by the $5\mu f$ capacitor is $35\mu c$. The potential difference (in V) between points a and b is:




$C_{5\mu} = \frac{q}{v} \rightarrow v = 7V$

$C_{7\mu} = \frac{q}{v} \rightarrow v = 5V$

$V_{a \rightarrow b} = 5 + 7 = 12v$

Q2) The capacitance of a single isolated spherical conductor with radius R is 5pF. if the charge on the capacitor is $85\mu C$, then the surface charge density (in$\mu C.m^{-2}$) is.

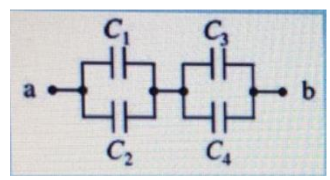
For isolated sphere

C=4πε∘ ∗R

R=0.04496

$\sigma = \frac{Q}{A} = 3346$

Q3) If $C_1 = C_3$=8.0$\mu f$, $C_2 = C_4$=16.0$\mu f$, and $Q_3$=15 $\mu C$ , then $Q_4$ (in $\mu C$) :

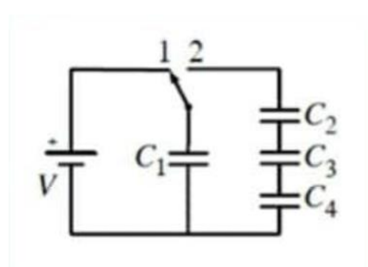



$V_{C_3} = \frac{Q_3}{C_3} = 1.875\ V$

$V_{C_3} = V_{C_4} = 1.875\ V$

$Q_4 = C_4 * V_{C_4} = 30\mu C$

Q4) The circuit shows a network of 4 identical capacitors. while the switch is in position 1, the capacitor $C_1$has a charge of 36 $\mu C$ . when the switch is moved to position 2, the charge (in $\mu C$) stored by capacitor $C_1$becomes:




$V_{C1} = V_{C2,C3,C4}$

$\frac{Q_1}{C} = \frac{3Q_2}{C}$

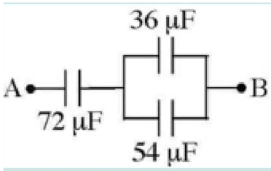
$Q_1 + Q_2 = 36\ \mu C$

$Q_2 = 36\ \mu C - Q_1$

$\frac{Q_1}{C} = \frac{3(36\ \mu C - Q_1)}{C}$

$Q_1 = 27\mu C$

Q5) If $V_A$-$V_B$=80 V, how much energy (in mJ) is stored in the 54- $\mu f$ capacitor.

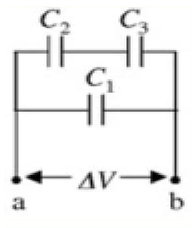



$$C_T = \frac{Q}{V_T} \rightarrow Q_T = 32 * 10^{-4}$$

$$V_{54} = V_T - V_{72} = 35.6$$

$$U = .5 * V_{54} * Q_{54} = 34.1mJ$$

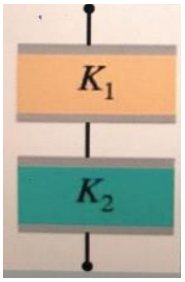
Q6) If $\Delta V$=12.0V and $C_1$=$C_2$=$C_3$= 2200pF, then the energy (in J) stored in the capacitor network is:




$$U = .5 * C_T * {V_T}^2$$

$$U = .5 * 3.3 * 10^{-9} * 12^2 = 2.37 * 10^7$$

Q7) Two identical parallel- plate capacitors each having plate area A=50.0$cm^2$and plate separation d=1.0 mm are completely filled with two different dielectrics of d dielectric constants $K_1$=2.0 AND $K_2$=6.8, and then connected as shown in the figure. the equivalent capacitance (in pF) of the combination is:



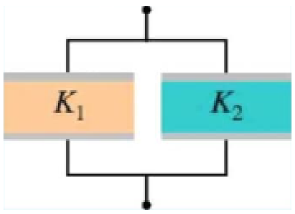

$$C = K * C_\circ = K * \frac{\varepsilon_\circ * A}{d}$$

$$C_1 = 8.85 * 10^{-11}$$

$$C_2 = 3.009 * 10^{-10}$$

$$C_1 and\ C_2 series\ then\ C_T = 6.838 * 10^{-11}$$

Q8) Two identical parallel- plate capacitors each having plate area A=50.0$cm^2$and plate separation d=1.0 mm are completely filled with two different dielectrics of d dielectric constants $K_1$=2.0 AND $K_2$=7.4, and then connected as shown in the figure. the equivalent capacitance (in pF) of the combination is:




$$C = K * C_\circ = K * \frac{\varepsilon_\circ * A}{d}$$

$$C_1 = 8.85 * 10^{-11}$$

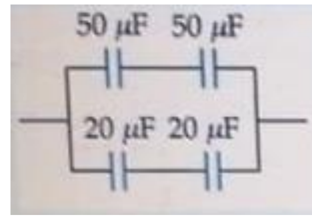
$$C_2 = 3.27 * 10^{-10}$$

$$C_1 and\ C_2 parallel\ then\ C_T = 4.1 * 10^{-11}$$

Q9) A 20 $\mu f$ capacitor is charged to 200 V . Its stored energy (in J) is .

$U = .5 * C * V^2 = 0.4\, J$

Q10) The equivalent capacitance (in $\mu f$) of the combination of the capacitors shown to the right is .



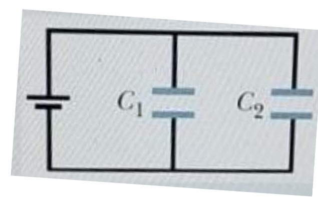

$C_{50}\ with\ C_{50}\ series = 25 * 10^{-6}$

$C_{20}\ with\ C_{20}\ series = 10 * 10^{-6}$

$C_{25} with C_{10} parallel$

$C_T = 10 * 10^{-6} + 25 * 10^{-6} = 35 * 10^{-6}$

Q11) Two parallel-plate capacitors of areas 4.89 $cm^2$ and 1.2 $cm^2$ , are connected in parallel to a battery. if the electric field between the plates has a magnitude of $E_1$= 2476.8 V/m and$E_2$=1039.3 V/m, he what is total charge on both capacitors?




$\mathrm{E} = \frac{\mathrm{Q}}{\varepsilon_\circ * \mathrm{A}}$

$\mathrm{Q}_1 = 1.072 * 10^{-11}$

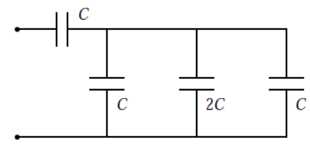
$\mathrm{Q}_2 = 1.103 * 10^{-12}$

$\mathrm{Q}_\mathrm{T} = \mathrm{Q}_1 + \mathrm{Q}_2 = 1.182 * 10^{-11}$

## {Done by: Omar Mohammad}

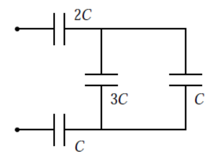
1-If $C$ = 15 mF, determine the equivalent capacitance for the combination shown.

**a.** 20 mF **b.** 16 mF **c.** 12 mF **d.** 24 mF **e.** 75 mF




2-If $C$ = 50 nF, determine the equivalent capacitance for the combination shown.

**a.** 29 nF **b.** 0.19 $\mu$F **c.** 34 nF **d.** 0.23 $\mu$F **e.** 75 nF




3- The plates of a parallel-plate capacitor are 3.28 mm apart, and each has an area of 9.82 $cm^2$ . Each plate carries a charge of magnitude $4.35 * 10^{-8}$ C. The plates are in vacuum. What is the capacitance?

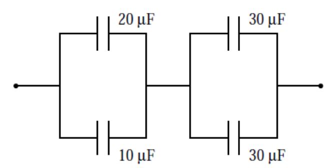
Answer: ………

4-A 5.00$\mu F$ parallel-plate capacitor is connected to a 12.0V battery. After the capacitor is fully charged, the battery is disconnected without loss of any of the charge on the plates.A voltmeter is connected across the two plates without discharging them. What does it read?

Answer: ………

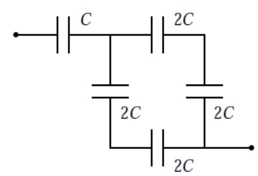
5-What is the equivalent capacitance of the combination shown?

**a.** 20 $\mu$F **b.** 90 $\mu$F **c.** 22 $\mu$F **d.** 4.6 $\mu$F **e.** 67 $\mu$F




6-If $C$ = 24 $\mu$F, determine the equivalent capacitance for the combination shown.

**a.** 20 $\mu$F **b.** 36 $\mu$F **c.** 16 $\mu$F **d.** 45 $\mu$F **e.** 27 $\mu$F




7- A cylindrical capacitor consists of a solid inner conducting core with radius 0.250 cm, surrounded by an outer hollow conducting tube. The two conductors are separated by air, and the length of the cylinder is 12.0 cm. The capacitance is 36.7 pF. Calculate the inner radius of the hollow tube.

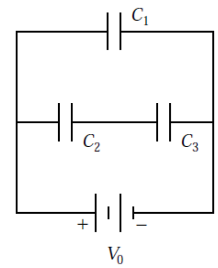
Answer: ………

8- A spherical capacitor contains a charge of 3.30 nC when connected to a potential difference of 220 V. If its plates are separated by vacuum and the inner radius of the outer shell is 4.00 cm, calculate: the capacitance?

Answer: .........

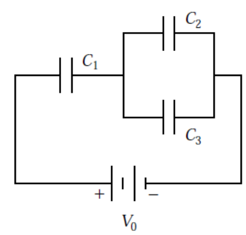
9-In the figure, if $C1 = 5.0\ \mu F$, $C2 = 15\ \mu F$, $C3 = 30\ \mu F$, $V0 = 24$ V, what is the total energy stored in the three capacitors?

**a.** 4.3 mJ **b.** 5.9 mJ **c.** 7.7 mJ **d.** 9.7 mJ **e.** 1.3 mJ




10-In the figure, if $C1 = 20\ \mu F$, $C2 = 10\ \mu F$, $C3 = 30\ \mu F$, and $V0 = 18$ V, determine the charge stored by $C1$.

**a.** 0.37 mC **b.** 0.24 mC **c.** 0.32 mC **d.** 0.40 mC **e.** 0.50 mC

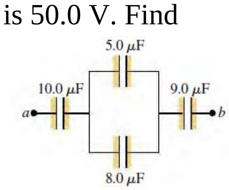



11- A spherical capacitor is formed from two concentric, spherical, conducting shells separated by vacuum. The inner sphere has radius 15.0 cm and the capacitance is 116 p.What is the radius of the outer sphere?

Answer: .........

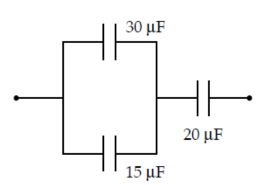
12-In figure shows a system of four capacitors, where the potential difference across *ab* is 50.0 V. Find the equivalent capacitance of this system between *a* and *b*.

Answer: .........



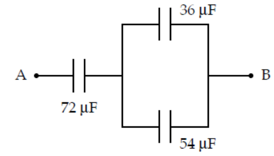

13-What is the total energy stored in the group of capacitors shown if the charge on the 30-μF capacitor is 0.90 mC?

**a.** 29 mJ **b.** 61 mJ **c.** 21 mJ **d.** 66 mJ **e.** 32 mJ



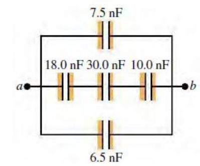
14-If $VA - VB = 50$ V, how much energy is stored in the 36-$\mu$F capacitor shown?

**a.** 50 mJ **b.** 28 mJ **c.** 13 mJ **d.** 8.9 mJ **e.** 17 mJ




15- For the system of capacitors shown in figure, a potential difference of 25 V is maintained across *ab*. What is the potential difference across the 7.5-nF capacitor?

Answer: .........




16- A 5.80$\mu F$, parallel-plate, air capacitor has a plate separation of 5.00 mm and is charged to a potential difference of 400 V. Calculate the energy density in the region between the plates, in units of J/$m^3$.

Answer: .........

17-If a 3.0-$\mu$F capacitor charged to 40 V and a 5.0-$\mu$F capacitor charged to 18 V are connected to each other, with the positive plate of each connected to the negative plate of the other, what is the final charge on the 3.0-$\mu$F capacitor?

**a.** 11 $\mu$C **b.** 15 $\mu$C **c.** 19 $\mu$C **d.** 26 $\mu$C **e.** 79 $\mu$C

18-A 25-$\mu$F capacitor charged to 50 V and a capacitor *C* charged to 20 V are connected to each other, with the two positive plates connected and the two negative plates connected. The final potential difference across the 25-$\mu$F capacitor is 36 V. What is the value of the capacitance of *C*?

**a.** 43 $\mu$F **b.** 29 $\mu$F **c.** 22 $\mu$F **d.** 58 $\mu$F **e.** 63 $\mu$F

19- A parallel-plate vacuum capacitor has 8.38 J of energy stored in it. The separation between the plates is 2.30 mm. If the separation is decreased to 1.15 mm, what is the energy stored if the capacitor is disconnected from the potential source so the charge on the plates remains constant

Answer: .........

20-A cylindrical air capacitor of length 15.0 m stores 3.20 $*10^{-9}$J of energy when the potential difference between the two conductors is 4.00 V. Calculate the magnitude of the charge on each conductor.

Answer: .........

21-A 4.0-mF capacitor initially charged to 50 V and a 6.0-mF capacitor charged to 30 V are connected to each other with the positive plate of each connected to the negative plate of the other. What is the final charge on the 6.0-mF capacitor?

**a.** 20 mC **b.** 8.0 mC **c.** 10 mC **d.** 12 mC **e.** 230 mC

22-A 15-$\mu$F capacitor and a 25-$\mu$F capacitor are connected in parallel, and this combination is charged to a potential difference of 60 V. How much energy is then stored in this capacitor combination?

**a.** 50 mJ **b.** 18 mJ **c.** 32 mJ **d.** 72 mJ **e.** 45 mJ

23- A capacitor is formed from two concentric spherical conducting shells separated by vacuum. The inner sphere has radius 12.5 cm, and the outer sphere has radius 14.8 cm. A potential difference of 120 V is applied to the capacitor. What is the energy density at *r* = 12.6 cm, just outside the inner sphere?

Answer: ………

24- A 12.5$\mu F$ capacitor is connected to a power supply that keeps a constant potential difference of 24.0 V across the plates. A piece of material having a dielectric constant of 3.75 is placed between the plates, completely filling the space between them. How much energy is stored in the capacitor before and after the dielectric is inserted?

Answer: ………

25-A 15-$\mu$F capacitor is charged to 40 V and then connected across an initially uncharged 25-$\mu$F capacitor. What is the final potential difference across the 25-$\mu$F capacitor?

**a.** 12 V **b.** 18 V **c.** 15 V **d.** 21 V **e.** 24 V

26-A 30-$\mu$F capacitor is charged to 80 V and then connected across an initially uncharged capacitor of unknown capacitance *C*. If the final potential difference across the 30-$\mu$F capacitor is 20 V, determine *C*.

**a.** 60 $\mu$F **b.** 75 $\mu$F **c.** 45 $\mu$F **d.** 90 $\mu$F **e.** 24 $\mu$F

27- The dielectric to be used in a parallel-plate capacitor has a dielectric constant of 3.60 and a dielectric strength of $1.60 * 10^{-9}$ V/m. The capacitor is to have a capacitance of $1.25 * 10^{-9}$ F and must be able to withstand a maximum potential difference of 5500 V. What is the minimum area the plates of the capacitor may have?

Answer: ………

28- When a 360-nF air capacitor (1nF = 10$*$ $10^{-9}$ F) is connected to a power supply, the energy stored in the capacitor is 1.85 $*$ $10^{-5}$J. While the capacitor is kept connected to the power supply, a slab of dielectric is inserted that completely fills the space between the plates. This increases the stored energy by 2.32 $*$ $10^{-5}$J. What is the potential difference between the capacitor plates?

Answer: ………

29-A parallel plate capacitor of capacitance $C$o has plates of area A with separation d between them. When it is connected to a battery of voltage $V$o, it has charge of magnitude $Q$o on its plates. The plates are pulled apart to a separation 2$d$ while the capacitor remains connected to the battery. After the plates are 2$d$ apart, the magnitude of the charge on the plates and the potential difference between them are:

**a.** $\frac{1}{2}Q$o, $\frac{1}{2}V$o **b.** $\frac{1}{2}Q$o, $V$o **c.** $Q$o, $V$o **d.** 2$Q$o, $V$o **e.** 2$Q$o, 2$V$o

30- A parallel plate capacitor of capacitance $C$o has plates of area A with separation d between them. When it is connected to a battery of voltage $V$o, it has charge of magnitude $Q$o on its plates. While it is connected to the battery, the space between the plates is filled with a material of dielectric constant 3. After the dielectric is added, the magnitude of the charge on the plates and the new capacitance are:

**a.** $\frac{1}{3}Q$o, $\frac{1}{3}C$o. **b.** $\frac{1}{3}Q$o, $C$o **c.** $Q$o, $C$o **d.** 3$Q$o, $C$o **e.** 3$Q$o, 3$C$o

| | | | | | |
|---|---|---|---|---|---|
| 1. | **c. 12** mF | 11. | 17.5 cm | 21. | **d.** 12 mC |
| 2. | **a .** 29 nF | 12. | $C_{eq} = 3.47\ \mu F$ | 22. | **d.** 72 mJ |
| 3. | $C = 2.65\ pF$ | 13. | **d.** 66 mJ | 23. | u= 1.63$*$ $10^{-4}$ $J/m^3$. |
| 4. | $V_{ab} = 12\ V$ | 14. | **d.** 8.9 mJ | 24. | $U_{before} = 0.0036\ J$ , $U_{after} = 0.0135\ J$ |
| 5. | **a. 20** $\mu$F | 15. | $V = 25\ V$ | 25. | **c.** 15 V |
| 6. | **c.** 16 $\mu$F | 16. | u= 0.028 $J/m^3$. | 26. | **d.** 90 $\mu$F |
| 7. | $r_b = 3\ cm$ | 17. | **a .** 11 $\mu$C | 27. | $A = 135\ cm^2$ |
| 8. | $C = 15\ pF$ | 18. | **c.** 22 $\mu$F | 28. | $V = 10.14\ V$ |
| 9. | **a. 4.3** mJ | 19. | $U_2 = U_1/2$ | 29. | **b.** $\frac{1}{2}Q$o, $V$o |
| 10. | **b.** 0.24 mC | 20. | $Q = 1.6\ nC$ | 30. | **e.** 3$Q$o, 3$C$o |