APB Giancoli

Ch16 $\vec{F_e}$, $\vec{E}$, Gauss. Electrostatics

16-1 ~ 16-4 . 4 Fundamental Forces

- Electrostatics Activity

- Coulomb's Law

$$\underset{\text{by 2 on 1}}{\vec{F}} = k_e \frac{q_1 q_2}{r^2}\hat{r}$$

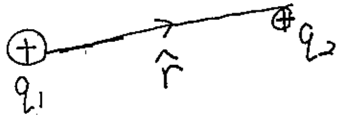
Coulomb's constant

- $k_e = 8.99 \times 10^9 \ Nm^2/C = \frac{1}{4\pi\varepsilon_0}$

$[q]$ = Coulomb

Charge is quantized

- $e = 1.6022 \times 10^{-19}$ C



- Permittivity of free space

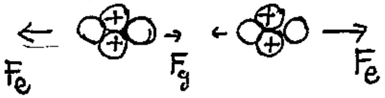
$\varepsilon_0 = 8.85 \times 10^{-12} \ C^2/Nm^2$

- $k_e = 10^{-7} C^2$ precisely !

- Conservative force

- $F_e \sim 10^{35} \times F_g$

α particle repulsion

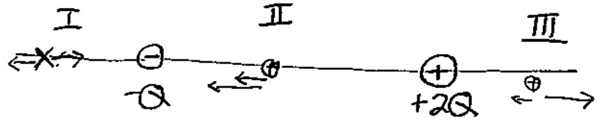


HS Quiz

- estimate # ~~charges~~ electrons on 2 balloons rubbed w/wool

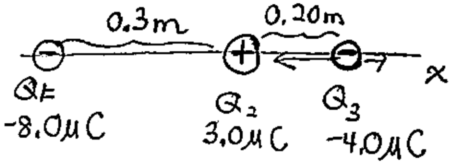
ex3 MTC

a) ✓



Where could F = 0 ? I only
(on +1 C charge)

b) skip



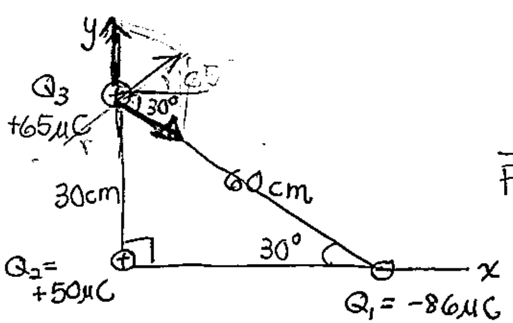
$\Sigma\vec{F}_{3 \text{ on } 3}$?

$kQ_3\left(-\frac{Q_1}{0.5^2} + \frac{Q_2}{0.2^2}\right)$

$= 8.99 \times 10^9 \times (4 \times 10^{-6})\left(-\frac{8 \times 10^{-6}}{0.5^2} + \frac{3 \times 10^{-6}}{0.2^2}\right)$

$= 10^{-3} \times -1548 = \boxed{-1.5N}$ left

✓ ex4 $\Sigma\vec{F}$ on Q_3 ?



$\vec{F_2} = \hat{j}\ 9 \times 10^9 \times 10^{-12} \frac{65 \times 50}{0.3^2}$

$= 325N\ \hat{j}$

$\vec{F_1} = 9 \times 10^{9-12} \times \frac{65 \times 86}{0.6^2} \langle \frac{\sqrt{3}}{2}, -\frac{1}{2} \rangle$

$= 140N \langle \frac{\sqrt{3}}{2}, -\frac{1}{2} \rangle$

$= \langle 121, -70 \rangle N$

$\Sigma\vec{F} = \langle 121N, 255N \rangle$

$|\vec{F}| = 280N$, 65° ∠

✓ ex5 Place $Q_4 = -50\mu C$ where for ΣF on Q_3 to be 0 ?

- In direction opposite $\Sigma\vec{F}$ in ex4

distance r = [illegible]

$\frac{kQ_4Q_3}{r^2} = 280$

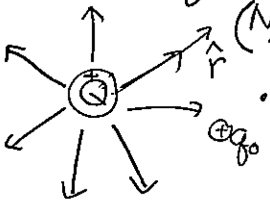
$r = \sqrt{\frac{9 \times 10^9 \times 65 \times 50 \times 10^{-12}}{280}}$

(16-8) 16-7 Electric Field

$$\boxed{\vec{E} \equiv \frac{\vec{F_e}}{q_0} = k_e \frac{Q}{r^2}\hat{r}}$$

(N/C)

$\vec{F_e} = q_0 \vec{E}$



- Test charge cancels out

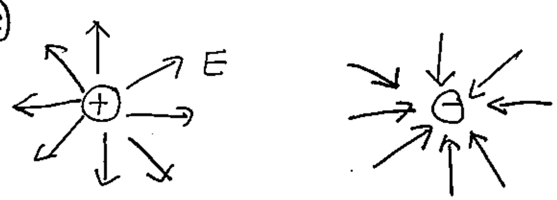
E independent of q_0

- field lines never cross

dir a + charge gets pushed

- denser means stronger field

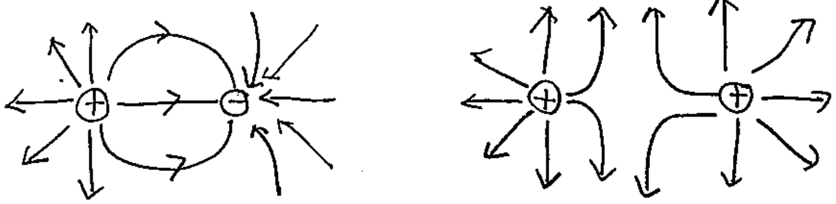
ⓐ



$\vec{E}$ · dir in $\vec{F}_e$ per 1C test charge

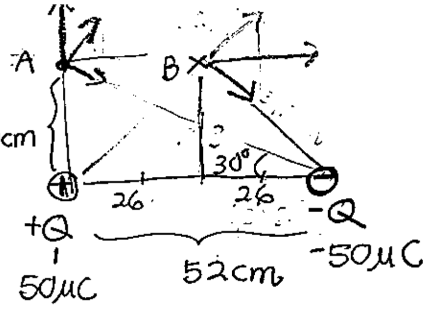
- never cross
- # lines ~ magnitude charge
- from + to −

double lines



see Holt figures

✓ 9 ex10



b) dir of E at B ?
to the right

a) $\vec{E}_A$?

a) $\vec{E}_+ = \frac{9\times10^{9-6}}{0.3^2}\times 50\ \hat{j} = 5.0\times10^6\ \frac{N}{C}\ \hat{j}$

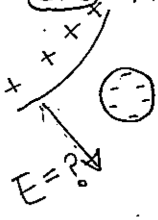
$\vec{E}_- = \frac{9\times10^{9-6}\times 50}{0.3^2+0.52^2}\left\langle\frac{\sqrt{3}}{2},-\frac{1}{2}\right\rangle$

$= 1.25\times10^6\ \frac{N}{C}\left\langle\frac{\sqrt{3}}{2},-\frac{1}{2}\right\rangle$

$\vec{E}_A = \langle 1.1, 4.4\rangle\times10^6\ N/C$

$|\vec{E}_A| = 4.5\times10^6\ N/C$, 76° ∠

ex6 Photocopy machine (see CISE ppt)

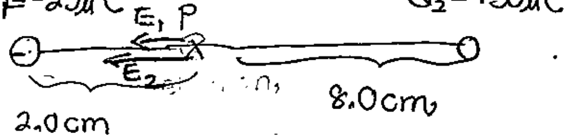


toner particle
$m = 9.0\times10^{-16}$kg
20 electrons extra

$F_e = 2F_g$

SKP $E = \frac{F_e}{q_0} = \frac{2mg}{20e} = \frac{2\times9\times10^{-16}\times9.8}{20\times1.6\times10^{-19}} = \boxed{5.5\times10^3\ N/C}$

✓ ex8 $Q_1 = -25\mu C$ $Q_2 = +50\mu C$

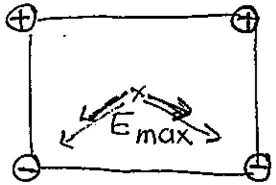


a) $\vec{E}_P$? $k_e\left(\frac{Q_1}{0.2^2}+\frac{Q_2}{0.8^2}\right)(-\hat{i}) = -6.3\times10^8\ N/C\ \hat{i}$

b) electron at P will accelerate $a = ?$

$\vec{a} = \frac{\vec{F}_e}{m_e} = \frac{e\vec{E}}{m_e} = \frac{1.6\times10^{-19}\times-6.3\times10^8}{9.11\times10^{-31}} = 1.1\times10^{20}\ m/s^2$

Ⓖ

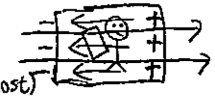


- 4 charges, mag same, sign dunno $\frac{kQ}{r^2}$ ①
- square
- How to get E_{max}? least cancel

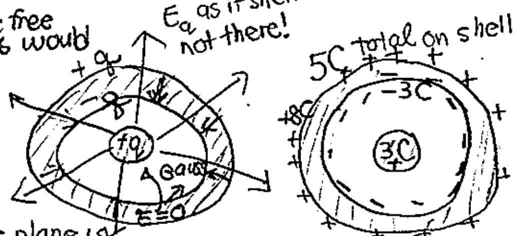
16-11 Phot Xerox
16-12 Gauss

16-9 Conductor in Electrostatic Equilibrium

① $\vec{E}_{in} = 0$
$Q_{in} = 0$ (repel most)



E=0 else free electrons would move



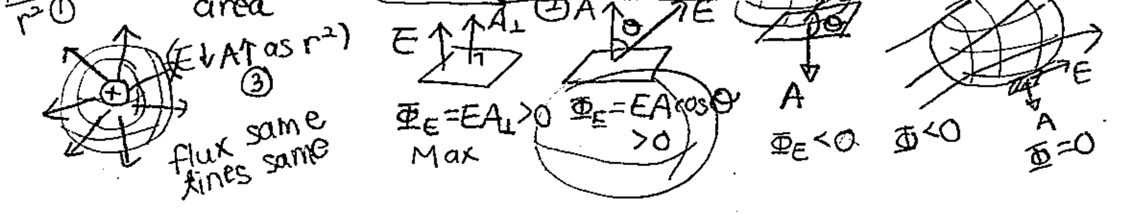
② $\vec{E}_\perp$ surface . else moves

- Infinite plane's
$|\vec{E}| = \frac{\sigma}{2\varepsilon_0}$ (prove by Gauss)

③ $\vec{E}_{big}$ at sharp corners ④ Conductor is equipotential surface.

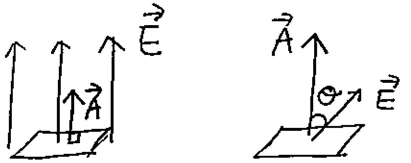
* 16-10 Gauss's Law

$E \sim \frac{\#lines}{area} \Rightarrow$ $\boxed{\Phi_E = \vec{E}\cdot\vec{A} = EA_\perp \sim \#lines \begin{array}{l} >0 \text{ out lines} \\ <0 \text{ lines in} \end{array}}$



$\boxed{16\text{-}10}$ Gauss's Law

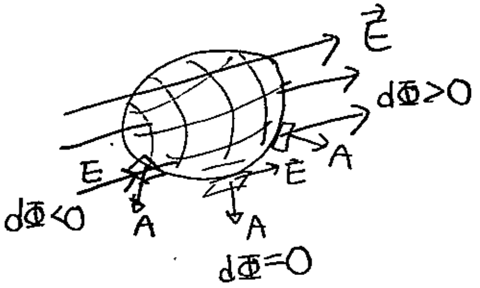
$$\boxed{\begin{aligned}\Phi_E &= \oint \vec{E}\cdot d\vec{A} = \#\text{lines out} - \#\text{lines in}\\ \text{net} &= \frac{Q_{in}}{\varepsilon_0}\end{aligned}}$$

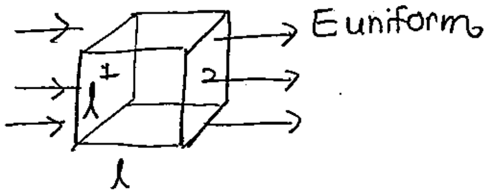


$\vec{E}\cdot\vec{A} = EA\cos\theta$

E

see YF

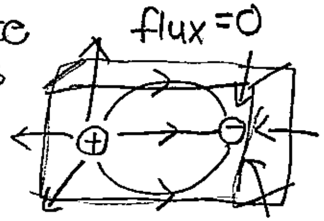


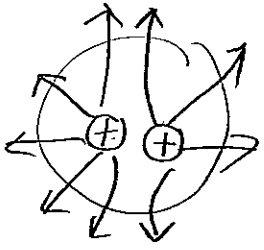


$\Phi_E = \Phi_2 + \Phi_1 + 0$

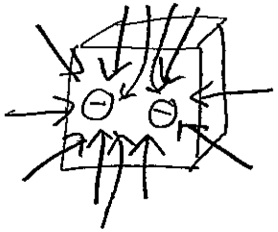
$= El^2 - El^2 = 0$

flux same any surface
same #lines



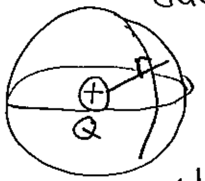


more flux

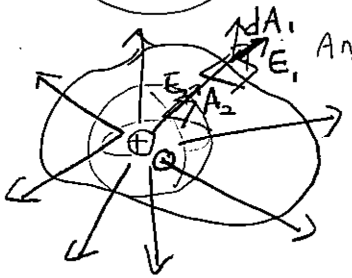


negative flux

Gauss 'Proof'



$\Phi_E = k_e\frac{Q}{\cancel{r^2}}4\pi\cancel{r^2} = \frac{Q}{4\pi\varepsilon_0}4\pi = \frac{Q_{in}}{\varepsilon_0}$



Any surface

$d\Phi_E = dA_1E_1\cos\theta = E_2dA_2$

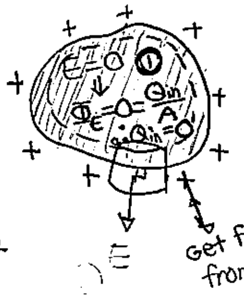
project on little sphere, same flux

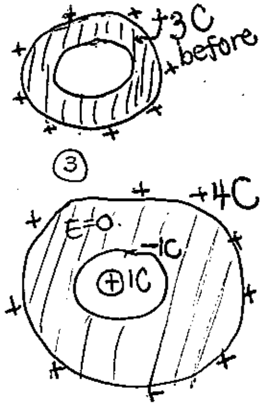
add up. weird's same flux as little sphere $= \frac{Q}{\varepsilon_0}$

Abnormal surface & many charges? Add up fluxes, still $\frac{Q_{in}}{\varepsilon_0} = \Phi_{Net}$

App: $\frac{\sigma}{2\varepsilon_0}$

Like $\boxed{\text{ex12}}$ Q must be on surface

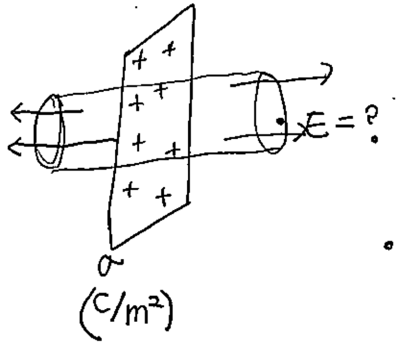




$E\cdot A = \frac{Q}{\varepsilon_0}$

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

ex Infinite sheet

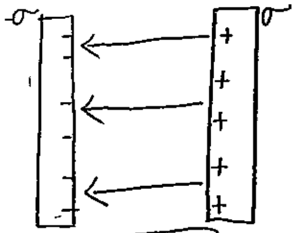


$$E2A = \frac{\sigma A}{\varepsilon_0}$$

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

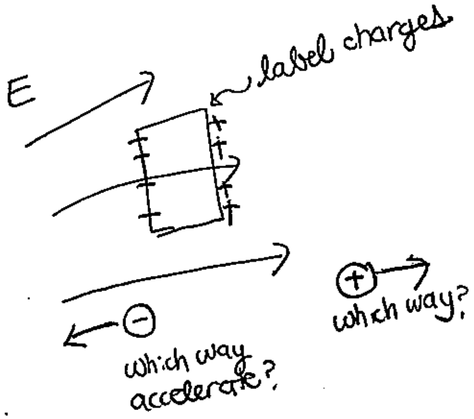
- distance does not matter (zoom in/out) same view

Capacitor: close together looks like infinite plane



$$\boxed{E = \frac{\sigma}{\varepsilon_0}}$$ uniform

Q



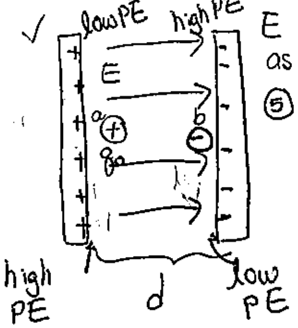
APB Giancoli -Go ~~thru HS PPT &~~ demo activities as intro.

PPT { Lecture Outline, HS Gen Sci, ~~APC Book~~ } - Make-up classes 2 wednesdays 100 min each

Ch 17 Electric Potential

(See HS Quiz ch5)

Capacitor



E uniform as discussed in ch16

⑤ Let go $\Delta PE \ \boxed{<0}$ $\Delta KE \ \boxed{>0}$ $W_{field} \ \boxed{>0}$

$\Delta V = \frac{-W_{field}}{q_0} = \frac{\Delta PE}{q_0} - \boxed{>0}$

★ $\vec{E}$ goes from high to low V potential ~~energy~~

Point Source

② Test charge q_0

Field does ⊕ work A) capacitor

Charge's KE ↑

So PE ↓ (if $\Sigma F = F_e$ field)

like capacitor (uniform E)

$$\boxed{W = \Delta KE = (-\Delta PE) = (qE)d \neq -W_{\text{by hand external}}}$$

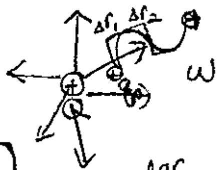
on charge by field

Generally

- To move a to b w/o accelerating, counteract the force

(from 17-5) C) General

If E not uniform



$\vec{E} \cdot d\vec{l}_1$

$W = q_0 E_1 \Delta r_1 + q_0 E_2 \Delta r_2 + \dots$

$= q_0 \int_a^b E(r)\,dr$

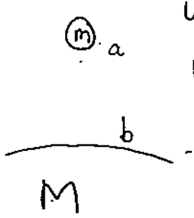
scalar $\Delta V = \frac{-W}{q_0} = \boxed{-\int_a^b \vec{E} \cdot d\vec{l}}$

$\Delta V = -E \Delta r$

$E(r) = -\frac{\Delta V}{\Delta r}$

Vector $\boxed{\vec{E} = -\vec{\nabla} V} = \langle -\frac{\partial V}{\partial x}, -\frac{\partial V}{\partial y}, -\frac{\partial V}{\partial z} \rangle$

① Gravity



a) $a \to b$

$W_{Earth} > 0$

$\Delta KE > 0$

$\Delta PE < 0$

-const. speed $W_{hand} < 0$

constant speed $b \to a$

$W_E < 0$

$W_{hand} > 0$

$\Delta KE = 0$

$\Delta PE > 0$

(Why'd ME change? W_{hand} nonconsv. into system)

b) Does PE or $\boxed{\Delta PE}$ have real meaning? only

any reference set to 0

Potential difference is what matters

c) What kinds of forces have PE defined? CONSERVATIVE { gravity, spring, electrostatic }

(Work independent of path, PE as storage bank)

③ $\boxed{\text{Potential (voltage)} = \text{Potential energy per unit charge}}$

$$\boxed{V = \frac{PE}{q_0}}$$

$\left[V = \frac{J}{C}\right]$ J/+1C

$$\boxed{\text{Voltage } \Delta V = \frac{\Delta PE}{q_0} = \frac{-W_{field}}{q_0} = \frac{+W_{ext}}{q_0}}$$

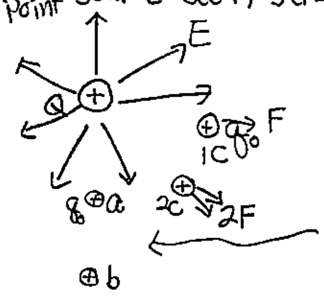
$\boxed{=Ed}$ uniform, capacitor

★ does NOT depend on test q_0, only on SOURCE

1.5 Volt battery: does 1.5 J per Coulomb $\boxed{\Delta PE = q_0 \Delta V}$

④ Why Joule per Coulomb?

B) Point Source -See 17-5 (P2)



bigger test charge, more push

$F_e = k_e \frac{Q q_0}{r^2}$

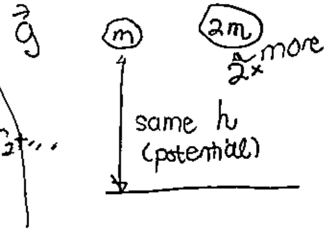
$E = \frac{F_e}{q_0} = k_e \frac{Q}{r^2}$ N/C depends only on Q

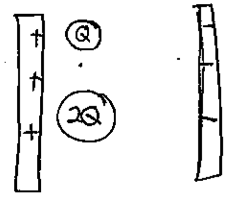
Work done = $F_e \Delta d = q_0 E \Delta d$ 2C has 2×work

(over tiny distance)

so ÷ q_0 away

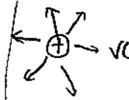
See Figure 17-3





⑤ Conceptual Example 1~~6~~7-1

General	Capacitor	Point Source
$\Delta PE = -q\int \vec{E} \cdot d\vec{l}$	$\Delta PE = -qEd$	
$\Delta V_{ab} = \frac{\Delta PE}{q_0} = \frac{-W_{field}}{q_0}$	$= \frac{W_{ext}}{q_0}$	
$= -\int_a^b \vec{E} \cdot d\vec{l}$	$\Delta V = Ed$	
V(x) = where is 0?		$V(r) = \frac{kQ}{r}$ V(∞)=0
$E = \frac{F}{q_0}$	$E = \frac{\sigma}{\varepsilon_0}$	$E = k\frac{Q}{r^2}$
$C = \frac{\Delta Q}{\Delta V}$	$C = \varepsilon_0 \frac{A}{d}$	$F = k\frac{qQ}{r^2}$



HS: is the bird safe? $C = \frac{R}{K}$

Table 17-1 Typical

outlet: 110 V, 220 V

Power line 10kV

auto battery 12V

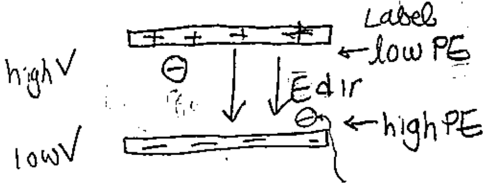
24V is dangerous

Refresher: (Faster/clearer)

-See APC Ch23 P8 note

ex2

Ⓠ Recap



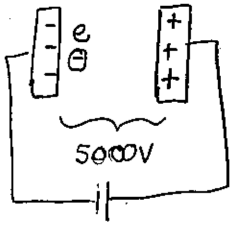
since $\Delta PE < 0$ $\Delta KE > 0$

$\Delta KE = W_{\text{by field}}$

$\Delta V = \frac{\Delta PE}{\text{per unit charge}} = \frac{W_{ext}}{\text{per unit charge}}$

APB Ch17 PI

ex2



electron let go

a) $\Delta PE \underset{\text{so}\uparrow\text{neg}}{=} -W_{field} = \overset{eEd}{\cancel{F_e d}} = e\Delta V = 1.602\times10^{-19}\times5000 = -8.0\times10^{-16}J$

b) $\Delta KE \underset{\text{gains}}{=} +8.0\times10^{-16}J$

c) speed at right? $= \frac{1}{2}\underset{9.11\times10^{-31}}{m}v^2 \Rightarrow v = \sqrt{\frac{2e\Delta V}{m}} = 4.2\times10^{7} m/s$

d) $d = 0.5m$ $\quad \Delta V = \frac{\cancel{e}Ed}{\cancel{e}}$

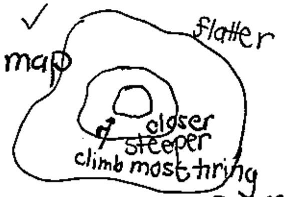
$E = ?\ \frac{\Delta V}{d} = 10\,000\ N/C \quad \overset{\checkmark}{\frac{V}{m}} = \frac{J}{mC} = \frac{N\cancel{m}}{\cancel{m}C}$

17-2

✓ ionizing air. Spark
Breakdown Voltage $(E > 3\times10^{6}\ V/m)$

ΔV so big, odd free e gains so much KE it knocks electrons out of O_2 & N_2 recombining with malecules ⇒ light

Figure 17-8
Go ⊥ equip curves that are close together
Like hiking. PE changes fastest
See topographic map ✓



17-3

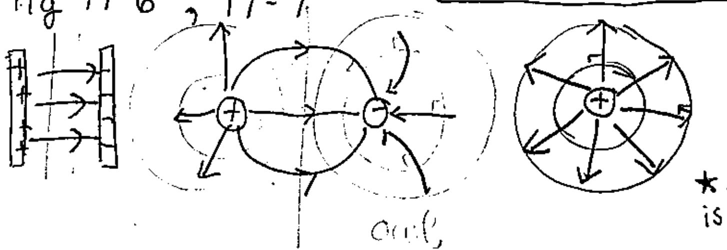
*field does no work

$\boxed{\text{Equipotential lines \& surfaces } \perp \vec{E}}$

where V = constant

$\boxed{V = \text{constant on \& in conductor in equilibrium}}$ else ΔPE will flow

See fig 17-6, 17-7



★ E points from high to low ✓

★ All the metal (cond in equilib) is an equipotential

$k = 8.99\times10^{9}\ Nm^2/C^2$
$\varepsilon_0 = 8.85\times10^{-12}$ $\quad \frac{1}{4\pi\varepsilon_0}$

17-4

electron volt (energy) work done on 1 electron in moving thru 1 Volt

$1eV \equiv \underset{C}{e}\times\underset{J/C}{1} = \boxed{1.602\times10^{-19}J}$

Useful:
- 1000V, 2 electrons move thru. work done = 2keV

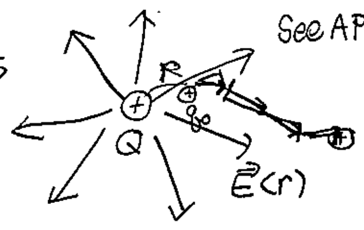
But to find speed, need Joules

✓ Ⓑ He^{2+} ion released from rest & accelerated thru 2.5kV 

Kinetic energy $= W_{field} = 2e\Delta V = \boxed{5keV} = \frac{1}{2}(\underset{amu}{m_p}4)v^2$

17-5

See Page 1



See APC pic

always +1C testcharge

PE? Set $PE_\infty = 0$

$\Delta V = \Delta PE/q_0$

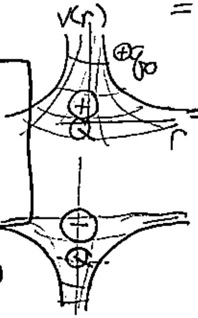
W_{ext} per unit charge to bring $+q_0$ from ∞ to r away (positive work)

$$\frac{W_{ext}\text{ to bring }+q_0\text{ from }\infty\text{ to }r\text{ away}}{q_0} = \frac{\ominus\cancel{q_0}\left(E_1(r)\underset{\ominus}{\Delta r_1} + E_2(r)\Delta r_2 + \dots\right)}{\cancel{q_0}}$$

$$= -\frac{\cancel{q_0}}{\cancel{q_0}}\int_\infty^R E(r)\,dr$$

$$= -\int_\infty^R \frac{kQ}{r^2}dr = kQ\int_\infty^R r^{-2}dr$$

$$= +kQ\left[\frac{1}{r}\right]_\infty^R = +kQ\left[\frac{1}{R} - \cancel{\frac{1}{\infty}}\right]$$

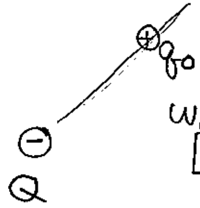


$$= +\frac{kQ}{R}$$

Q > 0, hand push out to keep from speeding up

$$= +\Delta PE$$

$$\boxed{V(r) = +k\frac{Q}{r} \\ V(\infty) = 0}$$



$V(\infty) = 0$

$W_{ext}\ \infty \to R\ \boxed{<0}$

$V(r) = k\frac{\overset{(-)}{Q}}{r}$

ⓜ $U(\infty) = 0$

Ⓜ

W_{ext} ∞ to R is negative!

$U(r) = -G\frac{M}{r}$

ex5 minimum work by external force to bring $q = 3.00\mu C$

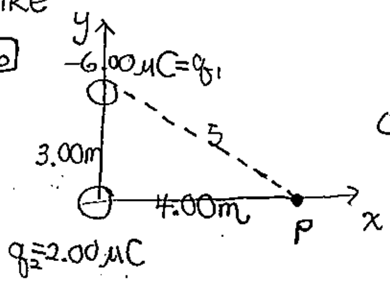
Gian from ∞ to 0.500m away from $Q = 20.0\mu C$?

$$W_{ext} = \Delta PE = q\Delta V = q(V_f - \cancel{V_0}) = q\left(\frac{kQ}{r} - \frac{kQ}{\infty}\right)$$
$\cancel{V_0}$ 0

$$= 3\times10^{-6}\left(\frac{9\times10^{9}\times20\times10^{-6}}{0.5}\right) = \boxed{1.08\,J}$$

YF like

ex6



a) total electric potential at P

b) work to bring q_3 from ∞ to P?

cb) $q_3 = 3.00\mu C$ placed at P

PE = ? of 3 particle system

a) $V_p = V_1 + V_2 = k\left(\frac{q_1}{r_1} + \frac{q_2}{r_2}\right) = 9\times10^9\left(\frac{-6\times10^{-6}}{5} + \frac{2\times10^{-6}}{4}\right)$

$= \boxed{-6.29\times10^3 V}$ To bring 1C from ∞ to P, $W_{ext} < 0$. Would attract by itself. Push against to go at v = const.

b) $q_3 V_p$

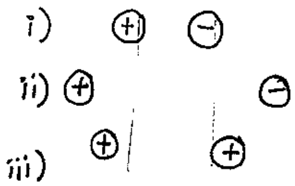
cb) PE = W_{ext} to move all 3 together

$$= W_{1\,near\,2} + W_{3\,near\,1} + W_{3\,near\,2}$$

$$= k\left(\frac{q_1 q_2}{r_{12}} + \underbrace{\frac{q_1 q_3}{r_{13}} + \frac{q_3 q_2}{r_{23}}}\right)$$

$$= 9\times10^9\left(\frac{-6\times2\times10^{-12}}{3}\right) - 6.29\times10^3 \times 3.00\times10^{-6} = \boxed{-5.48\times10^{-2} J}$$

ex7 ✓



(Q same)

a) positive PE? ΔKE↑ U ↘ $U_\infty = 0$ Ⓘⓘⓘ $\frac{kqQ}{r} = U$

b) most neg PE? ⓘ ↙ or most neg W_{ext} to bring together from ∞

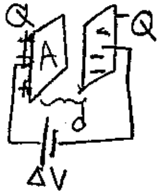
c) most work to separate to infinity? ⓘ

$\Delta PE = W_{ext}$ $\nearrow$ 0 PE

−PE

17-7 Capacitance

- stores charge



see Fig17-13

rolled up

- activated carbon

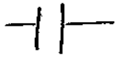
17-20 camera flash

17-21- defibrillator

-CRT, don't touch

17-17
- condensor in microphone
- keyboard key $\Delta d \to \Delta V$
- touchscreen

★ (depends on material, geometry)



$$\boxed{C \equiv \frac{\Delta Q}{\Delta V}}$$ C/V = Farad

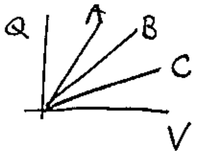
1pF, $10^3\mu F$ (common)

Parallel Plate

$$C = \frac{Q}{Ed} = \frac{\sigma A}{\sigma/\varepsilon_0\, d} = \boxed{\frac{\varepsilon_0 A}{d}}$$ ← Big C when?

- Area big (porous or rolled up)
- d small
- $\varepsilon = K\varepsilon_0$ big (dielectric material not air - stable - less breakdown - higher C)

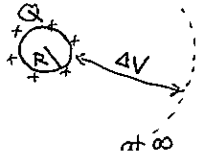
Ⓔ



Biggest C? A (steepest)

Lab: Given different batteries & 2 aluminum pie pans

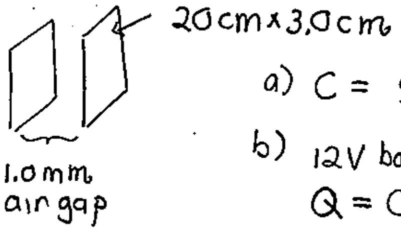
Ⓠ C_{sphere}? (Q no matter only geometry R)



$$C \triangleq \frac{Q}{\Delta V} = \frac{QR}{kQ} = \frac{R}{k}$$

(Holt Ch 17.2)

ex8



a) $C = \varepsilon_0 \frac{A}{d} = 8.85 \times 10^{-12} \times \frac{6 \times 10^{-3}}{10^{-3}} = 53pF$

b) 12V battery connected
$Q = C\Delta V = 53 \times 10^{-12} \times 12 = 6.4 \times 10^{-10} C$

c) $E = \frac{\Delta V}{d} = \frac{12}{10^{-3}} = 1.2 \times 10^{4} N/C \quad V/m$

d) If $C = 1F$, $d = 10 \mu m$ (10 microns), $A = ?$ $\frac{Cd}{\varepsilon_0} = 10^{6} m^2$

$\Delta V = \frac{(\cancel{q}E)d}{\cancel{q}}$

AP2
2015 MTC #18

17-8 Dielectric

= insulator put between plates { stable
increases C
less chance breakdown/discharge

$C = \underbrace{(K\varepsilon_0)}\frac{A}{d}$

ε permittivity

K dielectric constant >1 (=1 vacuum)

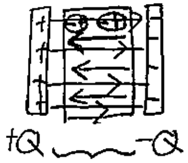
$K = \frac{C_{new}}{C_0} = \frac{E_0}{E_{new}} = \frac{\Delta V_0}{\Delta V_{new}}$ (considering net E)

$\frac{\cancel{Q}/\Delta V_n}{\cancel{Q}/\Delta V_0}$ Ed

(Table 17-3 shows breakdown E. Dielectric strength)

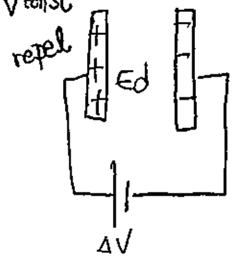
- Why does C increase? AP. How to measure K? what to find

Fig 17-19



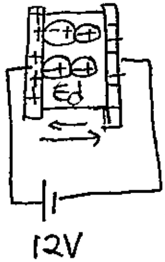
$C\uparrow = \frac{Q}{\Delta V \downarrow}$ does not change (disconnected from Battery)

$C = \frac{Q\uparrow}{V\ const}$ Before



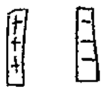
① same 12V

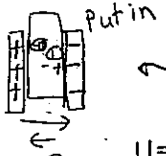
(repel & attract)
After



need more Q to have same Ed

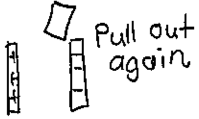
② Also, Q same





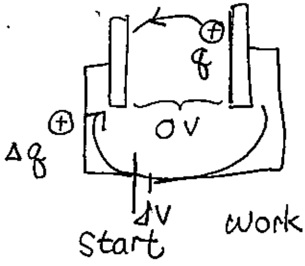
$\leftarrow C = \frac{Q\ const}{V\downarrow}$

$C = \frac{Q}{E\cancel{d}} \uparrow$ $U = \frac{1}{2}QV\downarrow$ energy to where? field pulled it in, did work $\longrightarrow$

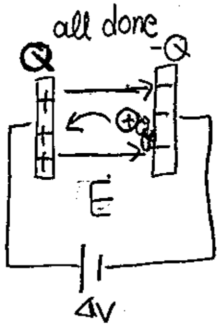


$U\uparrow$, $C\downarrow$ energy from? (hand does work, puts energy into dielectric-plate system)

17-9 Energy Storage



work=0



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

$\Delta PE = W_{ext}$ to bring Δq onto plate

work $= \Delta q\, V'_{avg}$

$$\boxed{= \frac{1}{2}Q\Delta V = \frac{1}{2}CV^2 = \frac{Q^2}{2C}}$$

☆ energy density (electrical Joule per unit volume)
True for any region containing $\vec{E}$ (light energy...)

$\frac{PE}{volume} = \frac{\frac{1}{2}CV^2}{Ad} = \frac{\frac{1}{2}\frac{\varepsilon_0 \cancel{A}}{\cancel{d}}(E\cancel{d})^2}{A\cancel{d}}$

$\boxed{u_E = \frac{1}{2}\varepsilon_0 E^2}$ J/m^3

$$work = \int_0^Q \Delta q\, V = \int_0^Q \frac{q}{C}\, dq = \frac{1}{C}\left[\frac{q^2}{2}\right]_0^Q = \frac{1}{2}\frac{Q^2}{C}$$

17-10

1 Byte = 8 bits → $2^8 = 256$ possibilities

- 17-4
- ADC fig 17-24, 25 (samples)
- Noise

17-11

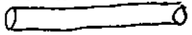
- CRT, oscilloscope
- RGB pixels on/off transistor (switch)

APB Giancoli

Ch18 · (Giancoli has all ch18 / see PPT)

- Battery

crowded tunnel



R big

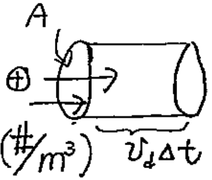
R small

$A = C/S$ 18-8

$$\boxed{I = \frac{\Delta Q}{\Delta t}} = \frac{e n v_d \cancel{\Delta t} A}{\cancel{\Delta t}} = n e v_d A \quad n(\#/m^3)$$

idea
switch light on
-E signals at c
-electron takes 1hr for 1meter

electron density



- $V = IR$ ohmic material, linear for a range of V, Temp.
experimental "law"

$$[R] = \Omega = \frac{V}{A} = \frac{J/C}{C/S} = \frac{JS}{C^2} = \frac{Nms}{C^2} = \frac{kg\,m^2}{C^2S^2}S = \frac{kg\,m^2}{SC^2}$$

Mr.Ohm capital omega

- $R = \rho \frac{l}{A}$

resistivity (not density), By material

$[\rho] = \Omega \cdot m$

- Temperature dependence

$$\rho = \rho_0[1+\alpha(T-T_0)]$$

$$R = R_0[1+\alpha(T-T_0)]$$

Temperature coefficient of resistivity $(C°)^{-1}$

Usually $T\uparrow$ $R\uparrow$ (semiconductors $\alpha < 0$, $T\uparrow R\downarrow$ free up electrons)

faster motion, more heat up
R big
collisions slow down electrons

$[W = A \cdot V = \frac{\cancel{C}}{S}\, J/\cancel{C}]$

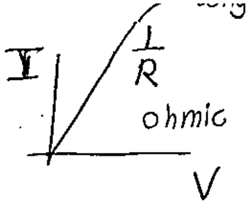
- $P = IV$

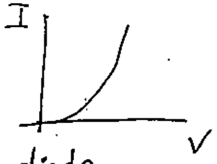
$$P = \frac{\text{energy}}{\text{time}} = \frac{\Delta Q\, \Delta V}{\Delta t} = \boxed{IV = I^2R = \frac{V^2}{R}}$$

(means difference now)

- 1kWh = energy of using 1000 W hairdryer for 1 hour
= $1000\,\frac{J}{S} \times 3600\,S = 3.6 \times 10^6\,J$

electric bill





diode
non-ohmic (19-2)

- AC ~see P2

-static WS

- Show basic ideas ppt
  - -series, parallel
  - -Christmas lights
- After Ch19 series, parallel R

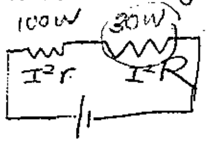
Household Ckts (G7, HS ppt)
- read a meter
- calculate electric bill
- wire house poster (18-6)

fuse, ckt breaker

CISE NTG 9,12 & Gian 21.11
wh -bulb a

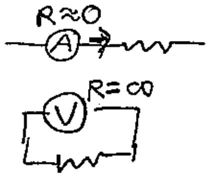
-CISE comic & check think
Ch9 NTG 1) $P\downarrow V\uparrow V$ α
both as test or source

- Parallel
  - $R_{tot}\downarrow$
  - P bigger
  - (branches)
- 100W vs. 30W
same V
Rsmall Rbig
- In series brighter!

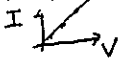


-finish static lab ppt

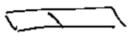
Short Lab on bulb Ckts → - 19-8 Ammeter / Voltmeter



Lab① Is it ohmic?
2 bulbs, 3 batteries, Ⓐ, Ⓥ
$\left(V=IR,\ I=\frac{V}{R}\right)$

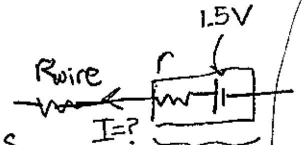


- new APB Lab
~ R strip



Lab② ★measure battery internal R (Hint: ex19-1)
~ wheatstone bridge

- Safety 19-7



$(V_{ext}=?)$

$\cancel{r = \frac{V}{I}}$

$V_{ext} \overset{?}{=} Ir$

$\star\ 1.5 - Ir = V_{ext}$

① 19-8 Shunt resistor

Circuit View
- electrons take 1hr to go 1m (why? nqv_dA) $v_{drift} \neq v$ between
- It's $\vec{E}$ set up when switch closes
- The signal to 'go' moves at lightspeed

All the ΔV is used up here (r brighter / R dimmer V^2/r | must be no matter the r)

actually r spread out but idealize here only over wires ↘

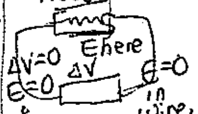
redox ΔV=9V

At first

like this
travel & Push

-need push → set up E to get thru opposition

now



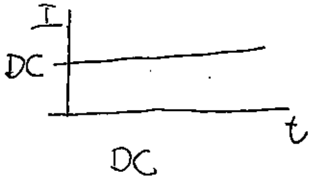
electrons go by inertia

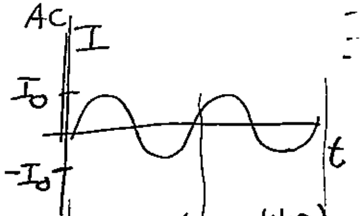
APB Ch 18~19 P1

18-7 AC ~ why? (see ppt G7 Generator)

$\bar{I} = 0$

$I_{rms} = E$





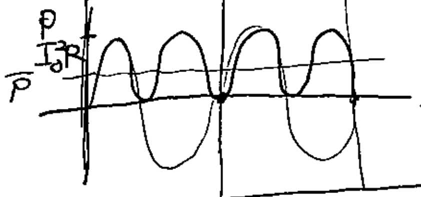
60 Hz

(SHM like) $\omega = 2\pi f$

Precal ⇒ $I(t) = ?$ $= I_0 \sin\left(\frac{2\pi}{T} t\right)$

$= \frac{V_0}{R}$

Power $= I_0^2 R \sin^2 \omega t$ $\sin^2\theta = \frac{1-\cos 2\theta}{2}$



$$\boxed{\bar{P} = \frac{1}{2} I_0^2 R = \frac{1}{2}\frac{V_0^2}{R} = I_{rms}^2 R = \frac{V_{rms}^2}{R}}$$

areas upsidedown

$\overline{\sin^2 \omega t} =$

$= \frac{\text{area}}{T}$

$$\boxed{\begin{array}{l}\bar{I} = 0 \\ I_{rms} = \sqrt{E[I^2]}\end{array}}$$

$\frac{I_1 + I_2 + \ldots + I_N}{N}$

OR area under curve ÷ T

$\overline{\sin^2 \omega t + \cos^2 \omega t} = \bar{1}$

$\underbrace{\overline{\sin^2 \omega t} + \overline{\cos^2 \omega t}}_{\text{same}} = 1$

$\therefore \overline{\sin^2 \omega t} = \frac{1}{2}$

$$= \sqrt{\frac{\int_0^T I^2(t)\,dt}{T}} \quad = \sqrt{\underbrace{\frac{1}{T}\int_0^T I_0^2 \sin^2 \omega t\,dt}}$$

calcAB

$$\underbrace{\frac{I_0^2}{T}\int_0^T \frac{1-\cos 2\omega t}{2}\,dt}\quad \left[\frac{1}{2}T - \cancel{\frac{\sin(2\omega \overset{2\pi}{T})}{2\cdot 2\omega}}\right] \to 0$$

$$= \sqrt{\frac{I_0^2}{2}} = \boxed{\frac{I_0}{\sqrt{2}}} \boxed{= 0.707 I_0}$$

$$\boxed{V_{rms} = \frac{V_0}{\sqrt{2}}}$$

- $V_{rms} = 110\text{ V} \Rightarrow V_0 = \sqrt{2} \times 110\text{ V} = 155\text{ V}$

- Mon: 19-3 ③ Kirchhoff

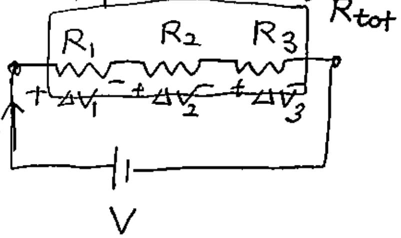
①Shunt 19-4 battery Charge up

②Cap 19-6 RC

19-2 Resistors : ~~S~~tudents derive themselves

In Series (impedance)

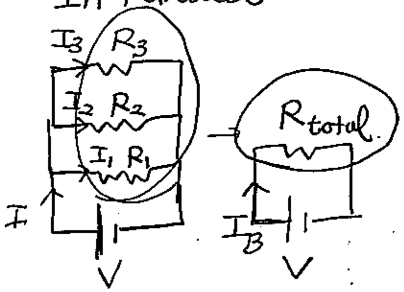
replace with equivalent R_{tot}



$\Delta V = \Delta V_1 + \Delta V_2 + \Delta V_3$

$= I \boxed{\underbrace{(R_1 + R_2 + R_3)}_{R_{tot}}}$

In Parallel



$I_B = I_1 + I_2 + I_3$

$\frac{V}{R_{tot}} = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3}$

$\therefore \boxed{\frac{1}{R_{tot}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}}$

must be $\bar{P}$

ex13
- Hair dryer 1500 W when 120 V-ac line
- Same power at 240 V ac line?
  (will have same R, P↑)
  same block, bigger push

$(\bar{P} = ?)$

- $\bar{P} = \frac{1}{2}\frac{V_0^2}{R} = \cancel{\frac{2}{2}}\frac{V_{rms}^2}{R} \Rightarrow R = \frac{V_{rms}^2}{\bar{P}} = \frac{120^2}{1500} = \boxed{9.6\Omega}$

- $\bar{P}_{Britain} = \frac{240^2}{R} = 4\bar{P} = \boxed{6000\text{ W}}$ melts!

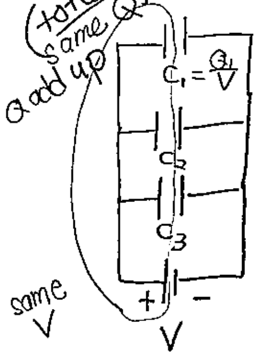
- 18-9 Superconductor
- Go back to P.1

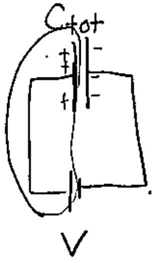
19.5 Capacitors

~get AP1-2 examples
& power stuff

Parallel

(increases area)
Q↑





$$C_{tot} = \frac{Q}{V} = \frac{Q_1+Q_2+Q_3}{V}$$

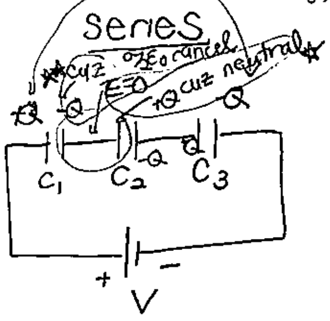
$$= \boxed{C_1+C_2+C_3}$$

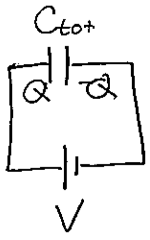
$> C_{individual}$ (same ΔV
more Q)

- See APC apps

★same (battery works
oxidize reduce
flows)

Series





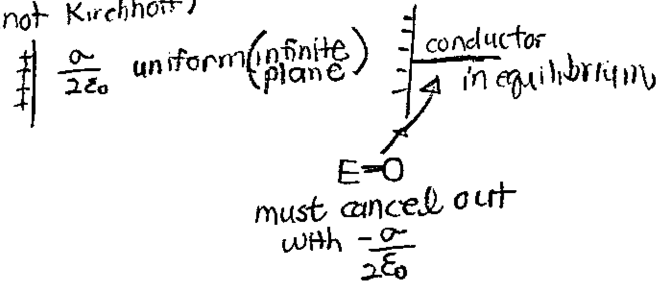
Q same
V_1 add up

$$C_{tot} = \frac{Q}{V} = \frac{Q}{V_1+V_2+V_3} = \frac{Q}{\frac{Q}{C_1}+\frac{Q}{C_2}+\frac{Q}{C_3}}$$

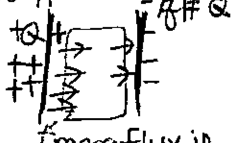
$$\boxed{\frac{1}{C_{tot}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} \ldots}$$

$C_{tot} < C_{individual}$
↑
same Q
but less ΔV (add up)

★★ why −Q?
(not Kirchhoff)



-OR, Gauss if



more flux in
than out
$Q_{in} \neq 0$
but vacuum!

- $R_{series/parallel}$ practice: HW & Lab measurement
- C " " : See APC

• See HS G7 ckt PPt - Household wiring & Safety

• Activities

① ⓐ
APC Ch25
House Cu
12 guage? wire (0.5Ω)

Short ckt
Not too long
r wire
r battery

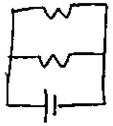
② Bulb, battery,
foil aluminum
Light up.
Note

$\underbrace{I^2R}_{glow} > \underbrace{I^2r}_{don't\ glow}$

ask: $R_{filament} \lesseqgtr r_{wire}$

③

I_1? I_2? I_B?
V_1? V_2? V_B?
R_1? R_2? R_B?
Brightness
Theory



④ House Ckt
diagram
- PIVR appliances (2 each)
- will the fuse blow?
- estimate kWh bill

⑤ finish static write-up

. Then show CISE NTQ
. Ch 19 Question 16

Ideally r=0 r=∞ but use shunt to deflect some current to sense (coil in magnet)

19-8 Ammeter, Voltmeter

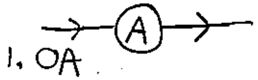
Shunt resistor (parallel) series resistance

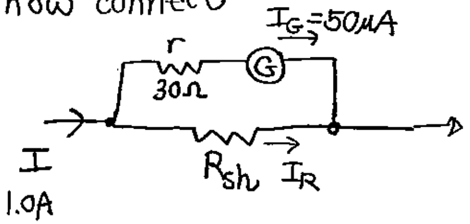
Ω ohmmeter

on AP2 now C?

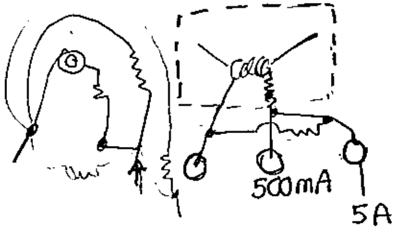
ex15 Needle deflects max 50μA, internal r = 30Ω when current thru is 1.0A (different R_{sh} for plugs)

- R_{sh} = ? and how connect





$$R_{sh} = \frac{50\mu 30}{1-50\mu} = \boxed{1.5\times10^{-3}\Omega}$$

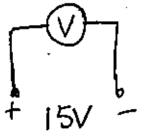


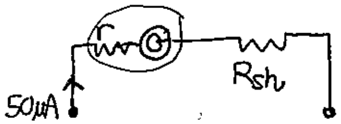
· r_{tot} ~0, smaller than smallest in parallel

· divert current to make smaller thru coil

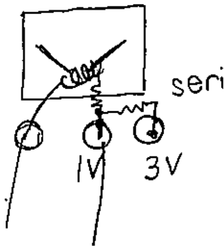
Google image or take apart?

ex16 As a voltmeter, r=30Ω, full scale I_G =50μA when 15V





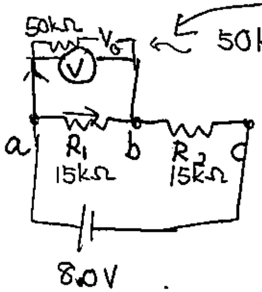
$$R_{sh} = \frac{15-50\mu 30}{50\mu} \approx \boxed{300k\Omega}$$



series makes i smaller

OK r~∞

ex17



← 50kΩ on 5.0V scale

V_{read} = ?

$$\frac{1}{R_{eq}} = \frac{1}{50k} + \frac{1}{15k} \Rightarrow R_{eq} = 11.5k\Omega$$

$$V_1 = 8 - 15k\left(\overset{I}{\frac{8}{11.5k+15k}}\right) = \boxed{3.5V}$$ low reading

$$V_{really} = 8 - 15k \times \frac{8}{30k} = 4.0V$$

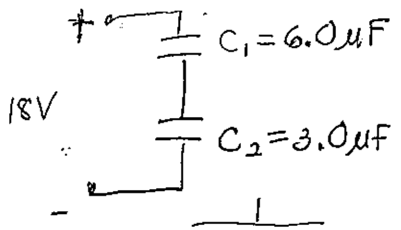
sensitivity 10000Ω/V ⇒ 5.0V scale ⇒ $\boxed{r = 50000\Omega}$

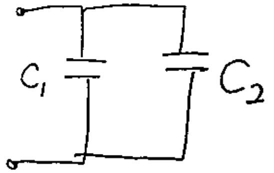
fig 21-42 tweeter

fig 19-23 Blinking traffic lights
P542 R windshield wipers
543 pacemaker
544 Safety
P846 Rectifier
853 #12

Ch18 P507 R color code
P513 Ckt breaker parallel
P517 Nerve
P536 Jumper Cable

ex5 · No CALC





$C_{eq}? = \frac{1}{\frac{1}{C_1}+\frac{1}{C_2}} = 2.0\mu F$

$Q ? = C_{eq}V = 36\mu C$

$V_1 ? = \frac{Q}{C_1} = 6.0\ V$

$V_2 ? = \frac{Q}{C_2} = 12.0V$

$C_{eq} = 9.0\mu F$

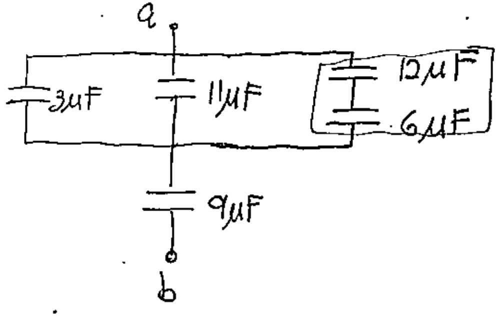
$Q_1 = C_1 V_1 = 108\mu C$

$Q_2 = C_2 V_2 = 54\mu C$

$V_1 = V_2 = 18V$

ex6 No CALC

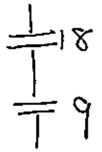
$C_{eq} \overset{?}{=}$



$\frac{1}{12}+\frac{1}{6} = \frac{3}{12} = \frac{1}{4} \rightarrow 4$

$3 + 11 + 4 = 18$

$\frac{1}{18}+\frac{1}{9} = \frac{3}{18} = \frac{1}{6}$



$\rightarrow$ $\boxed{6\mu F}$

but not as Battery
(since discharge $v\downarrow$
capacitor $v \neq$ constant)

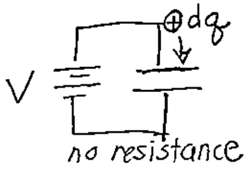
TYU ② 4μF & 8μF

a) How to let 4μF have more $\underline{\Delta V}$ than 8μF ?
$\frac{Q}{V}$ series $\frac{Q}{v}$

b) How to more $\underline{\text{charge}}$

parallel $\boxed{\text{cannot.}}$ since series same charge $\frac{Q\text{smaller}}{V\text{same}}$
series same Q

$\underline{24.3}$ Energy Storage in Capacitors



$C = \frac{q}{v}$

Charge up
work done to bring dq
thru potential v (joules/coulomb)

$dW = v\,dq = \frac{q}{C}dq$

$W = \frac{1}{C}\int_0^Q q\,dq = \boxed{\frac{Q^2}{2C} = \frac{1}{2}CV_{ab}^2 = \frac{1}{2}QV_{ab}}$

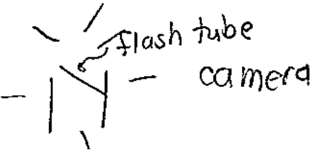
Also, like
$V = \frac{Q}{C}$, total work stored in V
energy per coulomb
$\underbrace{Q\times\left(\frac{Q}{C}\right)}_{\text{but} \div 2\ \text{avg since } \overset{q}{Q} \text{ went from } 0 \text{ to } Q} \quad \frac{Q^2}{C} \div 2$

★ work ~ $\frac{1}{C}$

Big C, less work energy stored. Depends on what is constant
$\frac{Q}{V}$ same V with Q buildup easier

Applications:

1) • store energy then — camera flash



Z machine Sandia National Labs nuclear fusion
> 1 million J released in few billionths second
2.9×10^{14} W power (80 × all power plants on earth combined)

3) slow release - ($\underset{\text{oscillate}}{LC}$) ac too
auto springs take jolt & spread energy over gradual oscillations
capacitor

2) HPF LPF (see APB) ac

X_c { high when f low (block, dc)
low when f high (no time to have effect of charge/discharge block)

4) Keyboard
5) Touchscreen

6) Pacemaker
Flashing Traffic Lights

energy density (J/m^3)

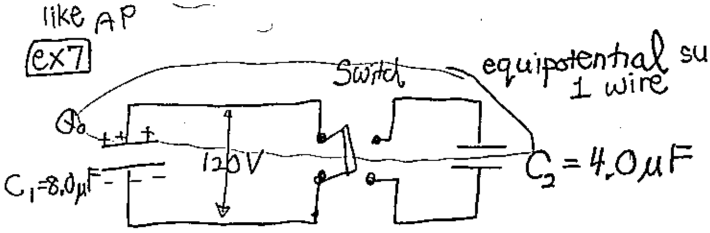
parallel plate

$$u = \frac{\frac{1}{2}CV^2}{Ad} = \frac{\frac{1}{2}\left(\varepsilon_0 \frac{A}{d}\right)(Ed)^2}{Ad}$$

$$= \boxed{\frac{1}{2}\varepsilon_0 E^2}$$ general! (vacuum any E field)

like AP

ex7



initially charged by 120V source with S open

Then, source removed

S open:

a) Q_0?

b) energy in C_1?

a) $C_1 = \frac{Q_0}{120}$

$Q_0 = 8\mu \times 120 = \boxed{960\mu C}$

b) $U_1 = \frac{Q^2}{2C} = \frac{1}{2}QV = \boxed{0.058J}$

S closed

c) Q_1? Q_2?

d) total energy in system?

S closed, parallel ~~Δ~~V

c) charge distributed & V will change but same across both

$Q_0 = Q_1 + Q_2$

$= C_1V + C_2V$ like equivalent capacitor

$V = \frac{Q_0}{C_1+C_2} = \frac{960\mu C}{(8+4)\mu F} = \boxed{80\ V}$

$\frac{960}{12}$

$Q_1 = C_1V = \boxed{640\mu C}$

$Q_2 = C_2V = \boxed{320\mu C}$

d) $U_{final} = \frac{1}{2}Q_1V + \frac{1}{2}Q_2V = \frac{1}{2}Q_0V$

$= \boxed{0.038J} < U_{initial}$

warmer wires

radiated waves

CH26, 31 Capacitor behavior in circuit

ex8 Store 1.00J PE in 1.00m^3 vacuum

a) How much E field needed?

b) if field 10× bigger, energy per cubic meter?

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

$E = \sqrt{\frac{2u}{\varepsilon_0}} = 4.75\times 10^5$ V/m ← half million volts across 1 meter

ε_0: 8.85×10^{-12} N/C (for insulator can make V this big)

b) $u \sim E^2$

$u = 1 \rightarrow \boxed{100 J/m^3}$

ex9 spherical capacitor of Ex3 +Q, −Q. electrical potential energy = ?

a) by using C

b) by integrating energy density

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

$$= \boxed{\frac{Q^2}{8\pi\varepsilon_0}\frac{r_b - r_a}{r_a r_b}}$$

b) $u = \frac{1}{2}\varepsilon_0 E^2 = \frac{1}{2}\varepsilon_0\left(\frac{1}{4\pi\varepsilon_0}\right)^2\left(\frac{Q}{r^2}\right)^2$

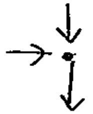
$= \frac{1}{32\pi^2\varepsilon_0}\frac{Q^2}{r^4}$ $dV = 4\pi r^2 dr$

$$U = \int_{r_a}^{r_b} u\,dV = \frac{Q^2}{32\pi^2\varepsilon_0}\int_{r_a}^{r_b}\frac{1}{r^4}(4\pi r^2)dr$$

$$= \frac{Q^2}{8\pi\varepsilon_0}\int_{r_a}^{r_b}\frac{1}{r^2}dr = \frac{Q^2}{8\pi\varepsilon_0}\left[\frac{-1}{r}\right]_{r_a}^{r_b} = \boxed{\frac{Q^2}{8\pi\varepsilon_0}\left[\frac{1}{r_a} - \frac{1}{r_b}\right]}$$

19-3 Kirchhoff's Rules

① Junction

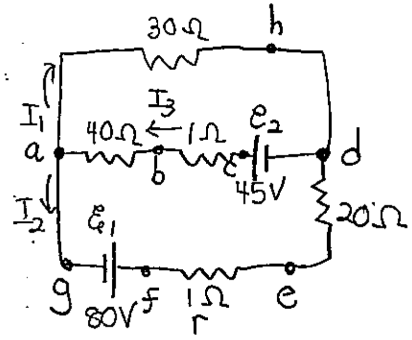


$I_{out} = I_{in}$

(Conservaton of charge)

② Loop rule ΔV across closed loop = 0
(energy is conserved)

ex8 I_1? I_2? I_3?



$$\begin{cases} I_3 = I_1 + I_2 \\ \text{Loop ahbd} \\ 45 - I_3\,41 - 30I_1 = 0 \\ \text{Loop ba ged} \\ 45 - 41I_3 + 80 - I_2\,21 = 0 \end{cases}$$

$$41I_3 = 125 - I_2\,21$$

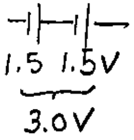
$$I_3 = \frac{45+41I_3}{30} + I_2$$

etc.

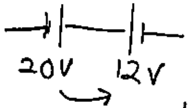
Solve rref $\begin{bmatrix} 1 & 1 & -1 \\ +30 & 0 & +41 \\ 0 & +21 & +41 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix} = \begin{bmatrix} 0 \\ +45 \\ +125 \end{bmatrix}$

$I_1 = -0.86$
$I_2 = 2.6$
$I_3 = 1.7A$

19-4 Emf's in parallel, Charging a battery

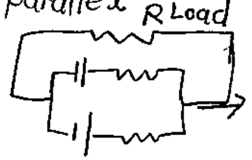


series



forces charge into 12V battery
- reversible chemical reaction in some batteries
(else wastes energy)

parallel



- each needs to provide less I for load
- less wasted
lasts longer too

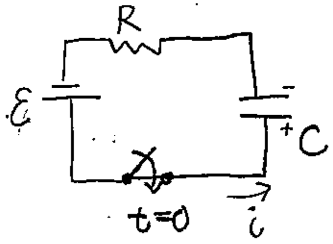
HW read ex9, E, Safety

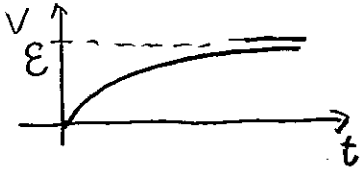
- ex9 71A vs 40A purpose of jump starting? - why E dangerous? I too big
- why is it safer to connect ground, car . order? H_2? (prevent short 100sA)

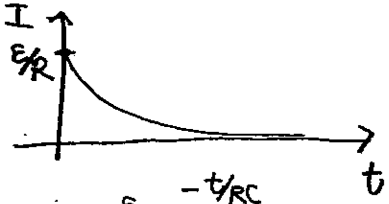
19-6 RC Circuits

C ~ high impedance open ckt for dc
low impedance closed ckt for ac

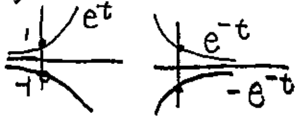
Charge Up:







Precal $\begin{cases} I(t) = \frac{\mathcal{E}}{R} e^{-t/RC} \\ V(t) = \mathcal{E}(1-e^{-t/RC}) \end{cases}$ $\quad Q(t) = C\mathcal{E}(1-e^{-t/RC})$



Time constant $\tau = RC =$ time for $I(\tau) = \frac{I_0}{e} = 0.37 I_0$

$V(\tau) = 0.63\mathcal{E}$

$C = \frac{\Delta q}{\Delta V} \Rightarrow \Delta V = \frac{\Delta q}{C}$

Calculus:

Kirchhoff: $\mathcal{E} - \frac{dq}{dt}R - \frac{q}{C} = 0 \longleftarrow$ Charge Up

$\mathcal{E} - iR - \frac{q}{C} = 0$

$\underbrace{i\mathcal{E}}_{\text{battery}} = \underbrace{i^2R}_{\text{resistor}} + \underbrace{\frac{iq}{C}}_{\text{charge up}}$

$\frac{dq}{dt} = \frac{\mathcal{E}}{R} - \frac{q}{RC}$

PE $\frac{dq}{q-f}$

AP2 Practice

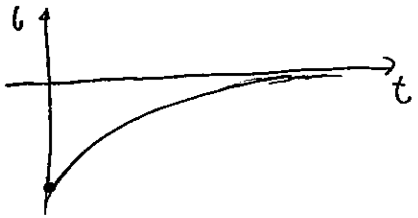
- Sawtooth Wave

Blinking light, turnlight, windshield wiper

RC → frequency

Discharge

$q(t) = Q_0 e^{-t/RC}$

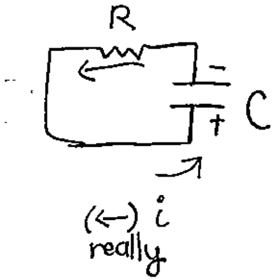


$i = \frac{dq}{dt} = I_0 e^{-t/RC}$

$-\frac{Q_0}{RC} e^{-t/RC}$

$\overbrace{i^2R}^{\text{dissipate}} = \overbrace{-\frac{iq}{C}}^{\text{loss}}$

i



$-iR - \frac{q}{C} = 0 \swarrow$

$\frac{dq}{dt} = \frac{-q}{RC}$

$\int_Q^q \frac{dq}{q} = \int_0^t -\frac{1}{RC} d\tilde{t}$

$\ln\left(\frac{q}{Q}\right) = -\frac{t}{RC}$

$q = Qe^{-t/RC}$

Electrostatics Demos

AP Physics

Explain what happened.
Keywords: friction, induction, conduction

1) a) Pith balls, plastic rod, wool observations
   b) Get the pith balls to repel each other

2) a) Get the balloon to stick on the wall
   b) Put moisture on the balloon. Still sticks?

3) Knowing the wool gives electrons to the balloon, figure out if the silk makes the glass rod positive or negatively charged.

4) Van de Graaff Generator Video
   a) Hair b) cupcake tins c) lightning
   d) fluorescent light e) bubbles

5) Get the electroscope wings to stay up horizontally. You may only touch the metal once and for less than half a second.

6) a) Which of the 4 basic forces is the contact force?
   b) How does a microwave heat food up?
   c) Is it better to wear conductive or insulating shoes at a grain silo?
   d) How does lightning form?
   e) How do lightning rods work?
   f) How to avoid static cling?
   g) Why are good thermal conductors also good electrically?
   lecular level
   h) How does a CRT work?

17 Q17

dielectric is pulled out from between the lates of a capacitor which remains onnected to a battery, What changes occur o (and why)

the capacitance

charge on the plates

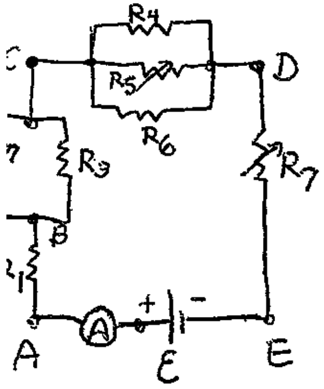
the potential difference

energy stored in the capacitor

the electric field

APB Giancoli Ch19 Q16 (also in Test)

ll in (↑ ↓ same)



a) $R_7 \uparrow \Rightarrow \Delta V_{AE}$ ____ (no resistance in Ⓐ & ε)

b) $R_7 \uparrow \Rightarrow \Delta V_{AE}$ ____ (there is resistance in Ⓐ & ε)

c) $R_7 \uparrow \Rightarrow \Delta V_4$ ____

d) $R_2 \downarrow \Rightarrow I_1$ ____

e) $R_2 \downarrow \Rightarrow I_6$ ____

f) $R_2 \downarrow \Rightarrow I_3$ ____

g) $R_5 \uparrow \Rightarrow \Delta V_2$ ____

h) $R_5 \uparrow \Rightarrow \Delta V_4$ ____

i) $R_2 \uparrow\ R_5 \uparrow\ R_7 \uparrow \Rightarrow \mathcal{E}$ ____ $(r_{internal} = 0)$

3 Try Wheatstone Bridge Lab

4 APB Sample 24

Conducting sphere X is initially uncharged. Conducting sphere Y has twice the diameter of sphere X and initially has charge 5C. If the spheres are connected by a long thin wire, ~~which~~ when equilibrium is reached describe

a) $V_X \; \underline{< = >} \; V_Y$

b) $E_X \; \underline{< = >} \; E_Y$

c) Sketch $\vec{E}$. Why the direction?

d) $E_{inside\,X} =$ ____ why?

e) $Q_{inside\,X} =$ ____ why?

f) $E_{\substack{right\\outside}}$ conductor = ____

5 The separation between the plates of an isolated charged parallel plate capacitor is increased slightly. Fill in (↑ ↓ same) and why.

a) C ____

b) stored electrostatic energy ____

- Give the 3 expressions for energy stored in a capacitor

c) Q ____

d) force of attraction ____

e) electric field magnitude ____

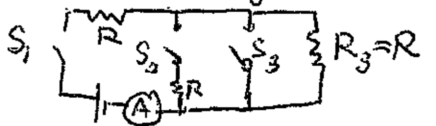
- Give the expression for capacitor $E =$ ____

f) V ____

Expression $V =$ ____

g) energy density $u_E =$ ____ J/m^3

6 APB Sample 28. Show why



Closing which switches will produce the greatest voltage across R_3?

A) S_1 only

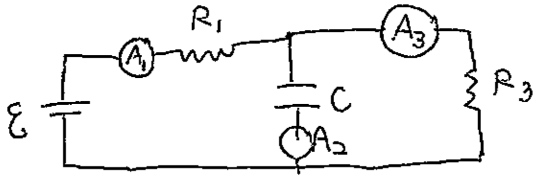
B) S_2 only

C) S_1 & S_2 only

D) S_1 & S_3 only

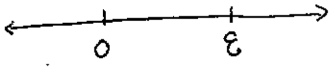
E) S_1, S_2, and S_3

AP2 MIC



16 a) Rank I_1, I_2, I_3

b) ΔV_c

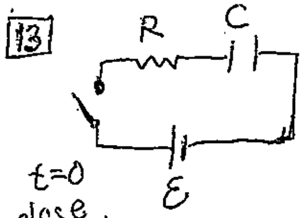


20

equipotential surfaces are shown

Rank the magnitude of E_A, E_B, E_C

13



t=0 close switch

a) At the moment the switch is closed,

$Q=$

$\Delta V_c=$

$i=$

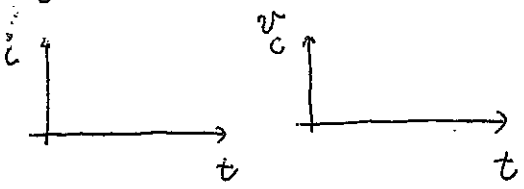
b) At steady state,

$Q=$

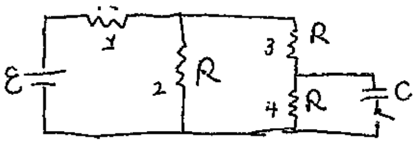
$\Delta V_c=$

$i=$

c)



5

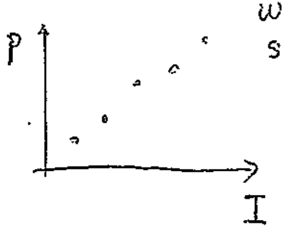


a) Switch is open rank $\Delta V_1, \Delta V_2, \Delta V_3, \Delta V_4$

b) Right after switch is closed current through battery is I_ε. What's I_2?

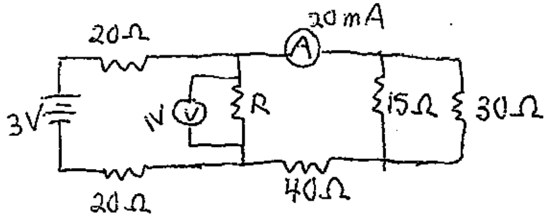
c) After a long time closed, brightness of bulb 4 compared to before the switch was closed?

21



what does the slope represent?

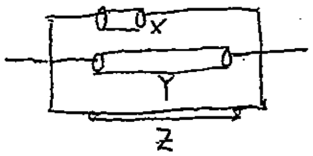
37



a) $i_{40}=?$

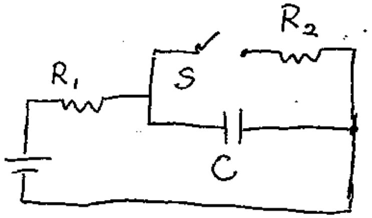
b) $R=?$

39



rank I_X I_Y I_Z

40



Compare energy stored in C before & after the switch is closed.

	Heartbook Ckt	Statics
AP 1	#2	
AP2	#1,	2,3
AP1	18	25
AP2	25	4,5,6,7,8,9 FRQ 3

Labs

* ① Is it ohmic?

2 bulbs, 3 batteries, Ⓐ, Ⓥ

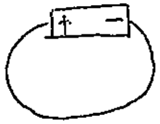
How? Errors?

② Light up. Bulb, battery, Al foil

$r_{filament} \overset{<}{\underset{>}{=}} r_{wire}$

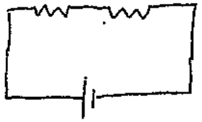
* ③ Internal Resistance (Hint: ex19-1)
Short Circuit (not too long)

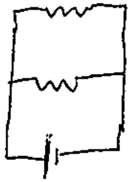
Ⓐ, Ⓥ



r_{wire}? $r_{battery}$?

④ 2 bulbs, 3 V, Ⓐ, Ⓥ





I_1? I_2? I_B?
V_1? V_2? V_B?
R_1? R_2? R_B?
Brightness?
Theory. r_{wire}

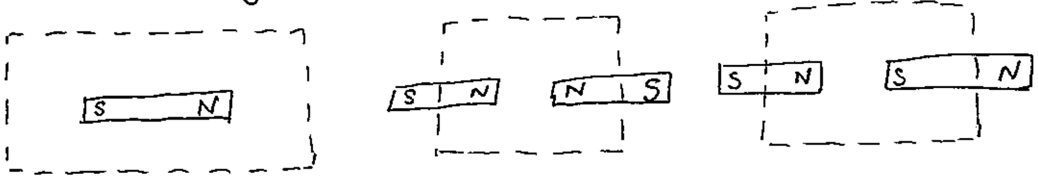
⑤ Classroom Circuit Diagram.

Will the fuse /circuit breaker trip?
blow

- PIVR appliances { laptop, water boiler, washer, μwave, light, fridge, hairdryer, heater, ac
- estimate kWh bill

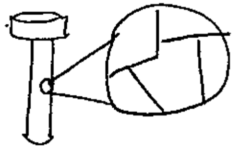
EM Demos

1) Draw the magnetic field lines

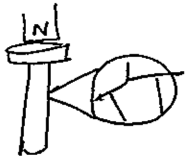


2) sketch domains

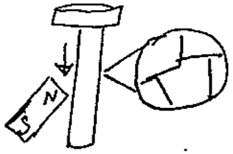
a)



b) Magnetize the iron



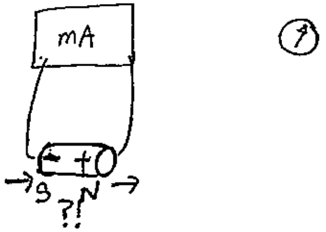
c) After stroked



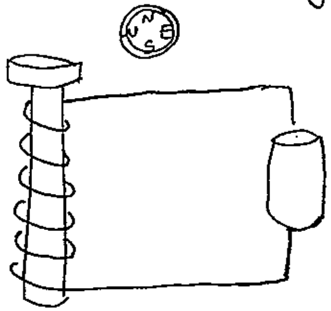
d) How to demagnetize?

e) How does magnetite form?

3) Demo Ampere's Law. Sketch ±V, I, B

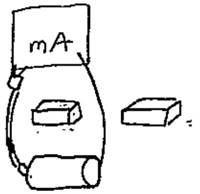


4) Create an electromagnet. Sketch ±V, I, B, N-S

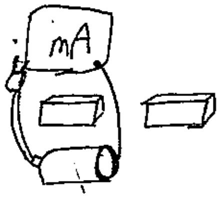


5) Demo Lorentz Force
Sketch ±, I, $\vec{B}$, N-S, $\vec{F}_B$

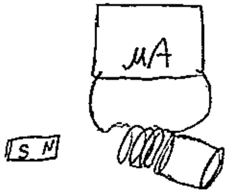
a) Pull wire up



b) Pull wire down



6) Demo Faraday's Law



7) Demo Motor

a) Draw

b) ______ → ______ energy

How does it work?

Demo Generator

a) Draw

b) ______ → ______ energy

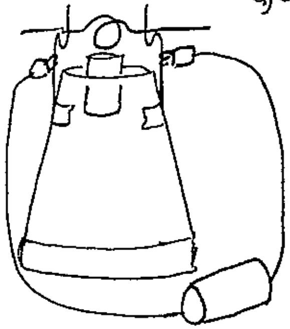
How does it work?

8) Build your own DC motor

a) Sketch ±V, I, $\vec{B}$, $\vec{F}$, rotatation, N-S (Lorentz force explanation)

b) Ampere's Law Reasoning:

c) How did you know what to sand off?



Chapter 10 Electromagnetism

Term	**Meaning**	**Picture**
Magnetic force		
Magnetic Field		
Magnetic Domain		
Atom as a Magnet		
Solenoid		
Electromagnet		
Earth's Magnetic Field		

Biot-Savart Law		
How a moving charge behaves in a magnetic field		
Electric Generator		
Electric Motor		
Maxwell's Wonderful Equations		
Gauss's Law		
Gauss's Law for Magnetism		
Ampere's Law with Maxwell's Correction		
Faraday's Law of Electromagnetic Induction		

APB Giancoli

Ch17 Q17

A dielectric is pulled out from between the plates of a capacitor which remains connected to a battery, What changes occur to (and why)

a) the capacitance $C = \frac{Q\downarrow}{\Delta V \text{ same}}$ (no induced charge) to cancel

b) charge on the plates $Q\downarrow$

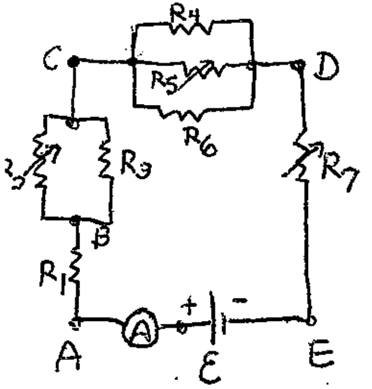
c) the potential difference same battery

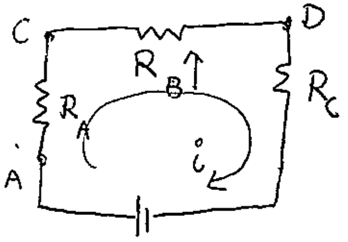
d) energy stored in the capacitor $\frac{Q^2}{2C} = \frac{1}{2}\overset{\downarrow}{Q}V = \frac{1}{2}\overset{\downarrow}{C}\underbrace{V^2}_{\text{same}}$

e) the electric field same total conceptually? (to push off Q use up energy)

2 APB Giancoli Ch19 Q16 (also in Test)

fill in (↑ ↓ same)





R↑ hogs voltage %
so V across it takes
up more of the ε

a) $R_7\uparrow \Rightarrow \Delta V_{AE}$ = same battery
(no resistance in Ⓐ & ε)

b) $R_7\uparrow \Rightarrow \Delta V_{AE}$ ↑ $R_{Tot}\uparrow$ $i\downarrow$ Less ir drop internal resistace
(there is resistance in Ⓐ & ε)

c) $R_7\uparrow \Rightarrow \Delta V_4$ ↓ $i_{tot}\downarrow$, less ir drop

d) $R_2\downarrow \Rightarrow I_1$ ↑ $r_{tot}\downarrow$

e) $R_2\downarrow \Rightarrow I_6$ ↑ $r_{tot}\downarrow$ $I_{tot}\uparrow$ $(\Delta V_{AC}\downarrow)$, $\Delta V_6\uparrow$

f) $R_2\downarrow \Rightarrow I_3$ ↓ $R_{AC}\downarrow$, $V_{AC}\downarrow$

g) $R_5\uparrow \Rightarrow \Delta V_2$ ↓ $V_{CD}\uparrow$ so $V_{AC}\downarrow$

h) $R_5\uparrow \Rightarrow \Delta V_4$ ↑

i) $R_2\uparrow$ $R_5\uparrow$ $R_7\uparrow \Rightarrow \varepsilon$ no change ($r_{internal}=0$)

3 Try Wheatstone Bridge Lab

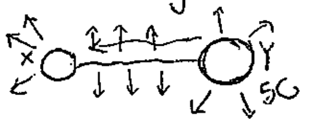
4 APB Sample 24

Conducting sphere X is initially uncharged
Conducting sphere Y has twice the diameter of sphere X and initially has charge 5C.
If the spheres are connected by a long thin wire, ~~which~~ when equilibrium is reached describe

a) V_x < [✓ =] > V_Y else flow

b) E_X < = [✓ >] E_Y sharp corner

c) Sketch $\vec{E}$. Why the direction?



d) $E_{inside\,x}$ = 0 why?

e) $Q_{inside\,x}$ = 0 why?

f) $E_{\substack{\text{right}\\ \text{outside}}} \text{ conductor} = \frac{\sigma}{2\varepsilon_0}$

*h) is 2.5 and 2.5 C ? NO

$\left[\begin{array}{l} \sigma_x 4\pi r_x^2 + \sigma_Y 4\pi r_Y^2 = 5C \\ Q_x + Q_Y = 5 \text{ coulombs} \\ \text{ratio ??} \end{array}\right]$

5 The separation between the plates of an isolated charged parallel plate capacitor is increased slightly.
Fill in (↑ ↓ same) and why.

a) C ↓ $C\downarrow = \varepsilon_0 \frac{A}{d\updownarrow}$ $U = \frac{1}{2}QV = \frac{Q^2}{2C} = \frac{1}{2}CV^2$

b) stored electrostatic energy: ↑
pull apart, energy into system

- Give the 3 expressions for energy stored in a capacitor

c) Q same

d) force of attraction same

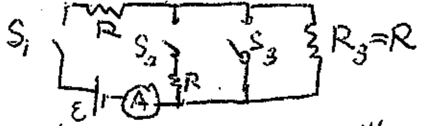
e) electric field magnitude $\frac{\sigma}{\varepsilon_0}$ same

- Give the expression for capacitor $E = \sigma/\varepsilon_0$

f) V = Ed ↑ increased
Expression V = Ed

g) energy density $u_E = \frac{1}{2}\varepsilon_0 E^2$ J/m³

6 APB Sample 28.
Show why



Closing which switches will produce the greatest voltage across R_3? $\left(\frac{\varepsilon}{2R}\right)\cdot R = \boxed{\frac{1}{2}\varepsilon}$

✓A) S_1 only

B) S_2 only → off

C) S_1 & S_2 only] S_2 makes parallel $R_{tot3}\downarrow$ Less ΔV across it Less %

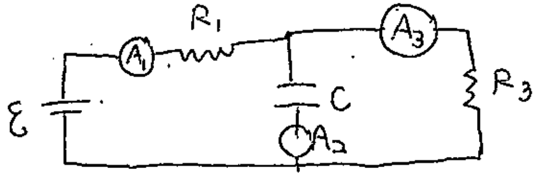
D) S_1 & S_3 only

E) S_1, S_2, and S_3] → $\Delta V_3 = 0$

$i = \frac{\varepsilon}{R + R/2} = \frac{2\varepsilon}{3R}$

$\left(\frac{2\varepsilon}{3}\right)\frac{1}{2} = \boxed{\frac{1}{3}\varepsilon}$

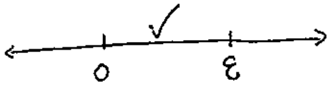
AP2 MIC 201~~6~~5



16 a) Rank $\overset{0}{I_2}$: I_1, I_2, I_3 =

$I_1 = I_3 > I_2 = 0$

b) ΔV_C



20

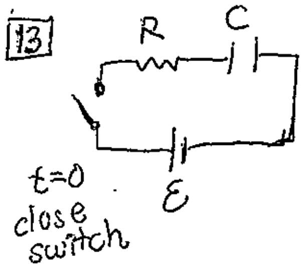
equipotential surfaces are shown

$E_A > E_C > E_B$

Rank the magnitude of E_A, E_B, E_C

contour closeness steep change

13



a) At the moment the switch is closed,

$Q = 0$

$\Delta V_C = 0$

$i = \varepsilon/R$

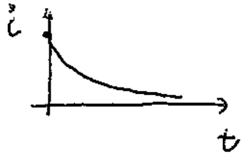
b) At steady state,

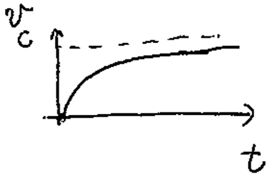
$Q = C\varepsilon$

$\Delta V_C = \varepsilon$

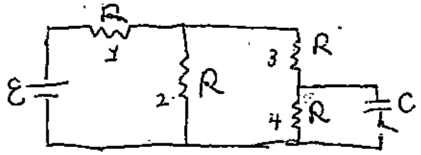
$i = 0$

c)





5 sample



a) Switch is open

rank $\Delta V_1, \Delta V_2, \Delta V_3, \Delta V_4$

$V_1 > V_2 = V_3 + V_4 > V_3 = V_4$

b) Right after switch is closed (drop iR_1)

current through battery is I_ε.

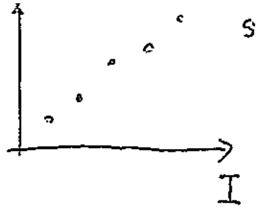
what's I_2? = half $I_B = \frac{1}{2}\frac{\varepsilon}{\frac{3}{2}R} = \frac{1}{3}\frac{\varepsilon}{R}$

$R + \frac{1}{2}R$

c) After a long time closed, brightness of bulb 4 compared to before the switch was closed?

same, C open ckt.

21

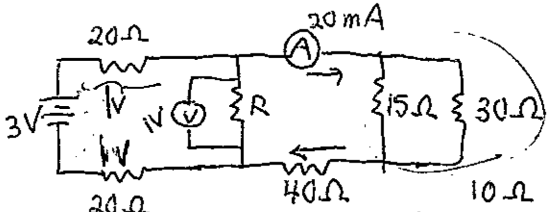


what does the slope represent?

$P = IV$

voltage

37

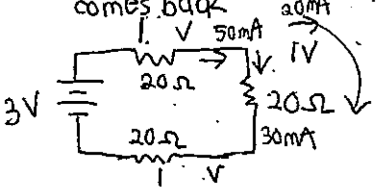


a) i_{40} = ? 20mA

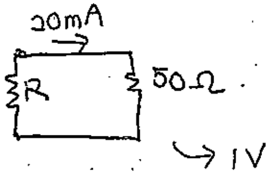
b) R = ?

$\frac{1V}{0.03A} = 33\Omega$

comes back

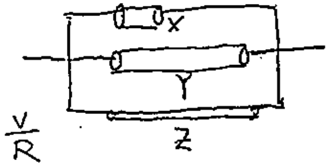


$\frac{1}{15} + \frac{1}{30} = \frac{3}{30} \to 10\Omega$



→ 1V

39



$\frac{V}{R}$

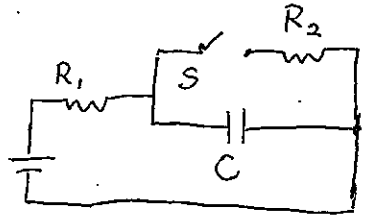
rank $I_X\ I_Y\ I_Z$

$R = \rho\frac{l}{A}$

$R_Z > R_Y > R_X$

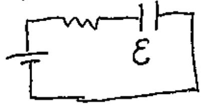
$I_Z < I_Y < I_X$

40



Compare energy stored in C before & after the switch is closed.

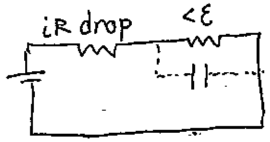
Before



$U = \frac{1}{2}CV^2$

same

After



$\boxed{\text{decreased}}$

Heartbook	Ckt MTC	Statics
AP 1	#2	
AP2	#1,	2,3
AP1	18	25
AP2	25	4,5,6,7,8,9 FRQ 3