PHYSICS 7LD LAB NOTES
SUMMER SESSION II 2003 - UCI

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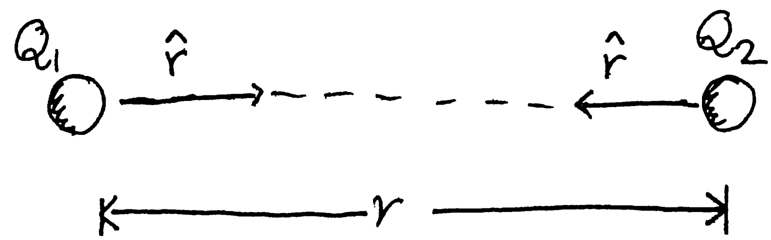
WEEK 1 - ELECTRIC FIELDS

COULDUMB'S LAW



$$\vec{F}_E = k\frac{-Q_1Q_2}{r^2}\hat{r} \qquad k = 9\times10^9\ \frac{Nm^2}{C^2}$$

NOTICE: • IF $Q_1Q_2 < 0$, $\vec{F}_E$ ATTRACTS.

THIS IS TRUE FOR CHARGES WITH OPPOSITE SIGN.

• IF $Q_1Q_2 > 0$, $\vec{F}_E$ REPELS.

THIS IS TRUE FOR CHARGES WITH THE SAME SIGN.

$\boxed{\text{UNITS: N (Newtons)}}$

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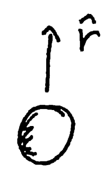
ELECTRIC FIELDS

DEFINE ELECTRIC FIELD "$\vec{E}$" AS



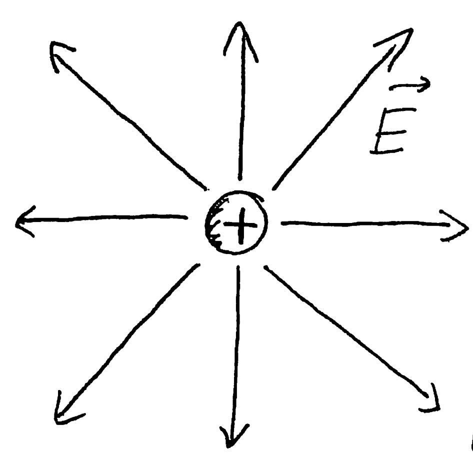
Q (either sign)

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

$\hat{r}$ POINTS OUTWARD ALONG RADIAL DIRECTION

$\boxed{\text{UNITS: N/C or V/m}}$

SO, ELECTRIC FIELD OF A POSITIVE CHARGE IS:



FORCE > 0 EVERYWHERE

- NOTE: $\vec{E}$ IS A VECTOR QUANTITY, WITH MAGNITUDE AND DIRECTION.

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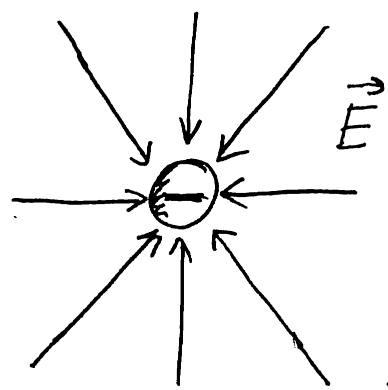
ELECTRIC FIELDS

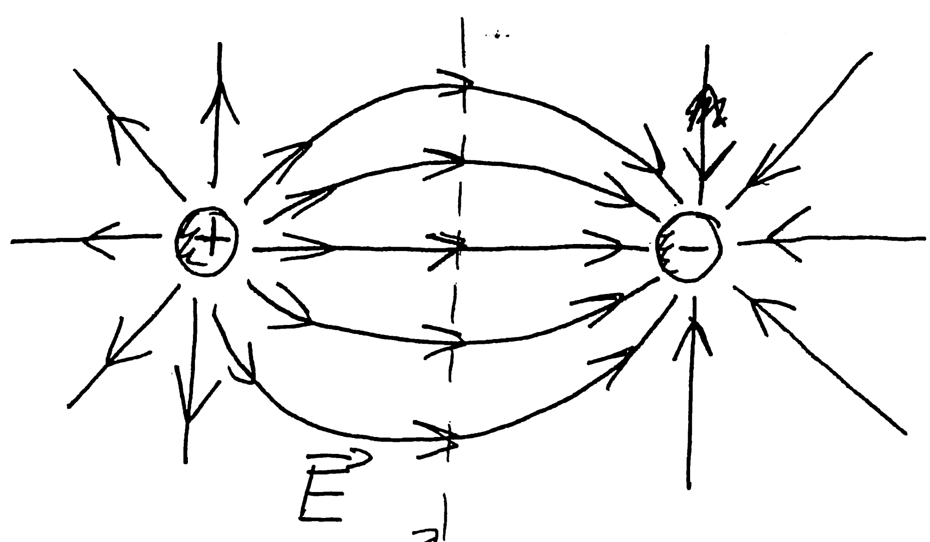
THE ELECTRIC FIELD OF A NEGATIVE CHARGE IS:



FORCE > Ø
EVERYWHERE

FOR POSITIVE CHARGES, FIELD LINES GO OUTWARD; WHEREAS FOR NEGATIVE CHARGES THE LINES GO INWARD.

THE ONLY CORRECT FIELD LINES FOR A POSITIVE CHARGE NEXT TO A NEGATIVE CHARGE ARE:



~~FORCE ALONG THIS LINE~~

ELECTRIC FIELDS

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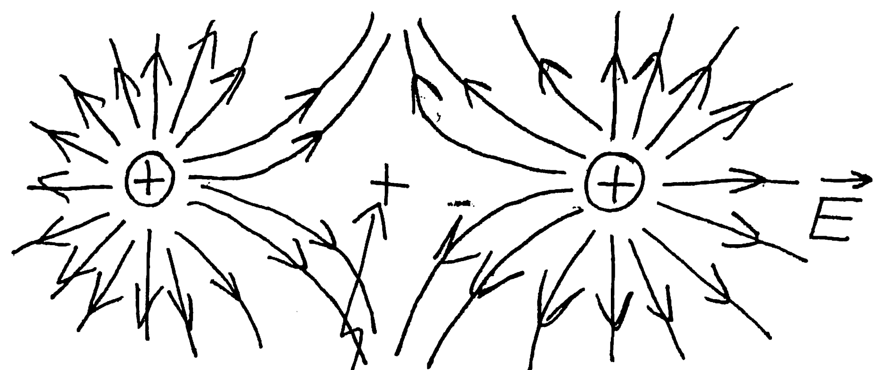
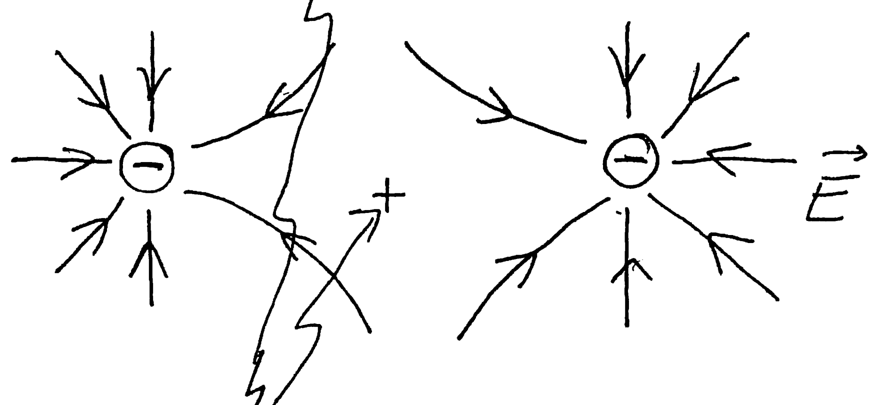
- FOR TWO POSITIVE CHARGES, THE FIELDS ARE:



- FOR TWO NEGATIVE CHARGES, THE FIELDS ARE:



FORCES ON
A CHARGE PLACED
HERE BALANCE.

SINCE THE ELECTRIC FIELD, $\vec{E}$, IS A VECTOR OVERLAPPING FIELDS COMBINE BY ADDING VECTORIALLY.

$$\vec{E}_{TOT} = \vec{E}_1 + \vec{E}_2 + \text{ETC...}$$

CALLED SUPERPOSITION.

ELECTRIC FIELDS

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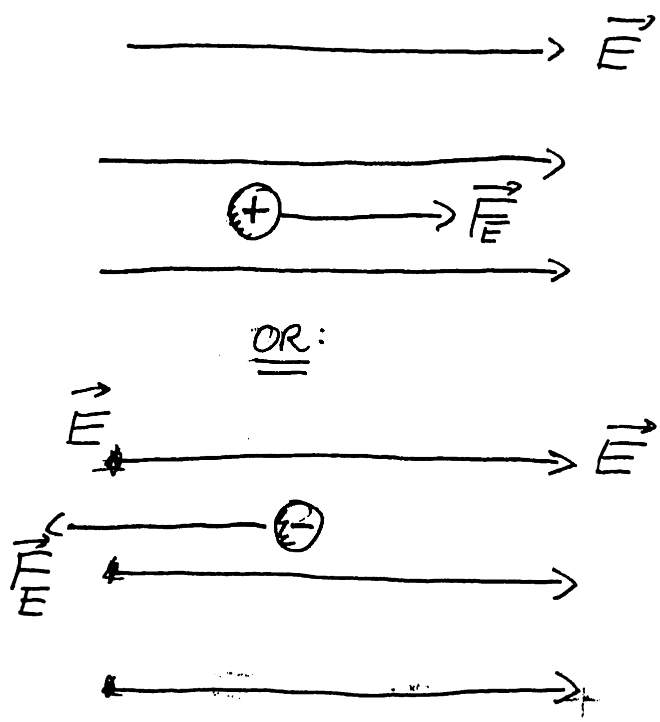
FORCE ON A CHARGE IN AN ELECTRIC FIELD:

PUT A CHARGE Q IN AN ALREADY-SET UP ELECTRIC FIELD $\vec{E}$.

FORCE IS:

$$\boxed{\vec{F}_E = Q\vec{E}}$$

Q IS SOMETIMES CALLED THE TEST CHARGE.



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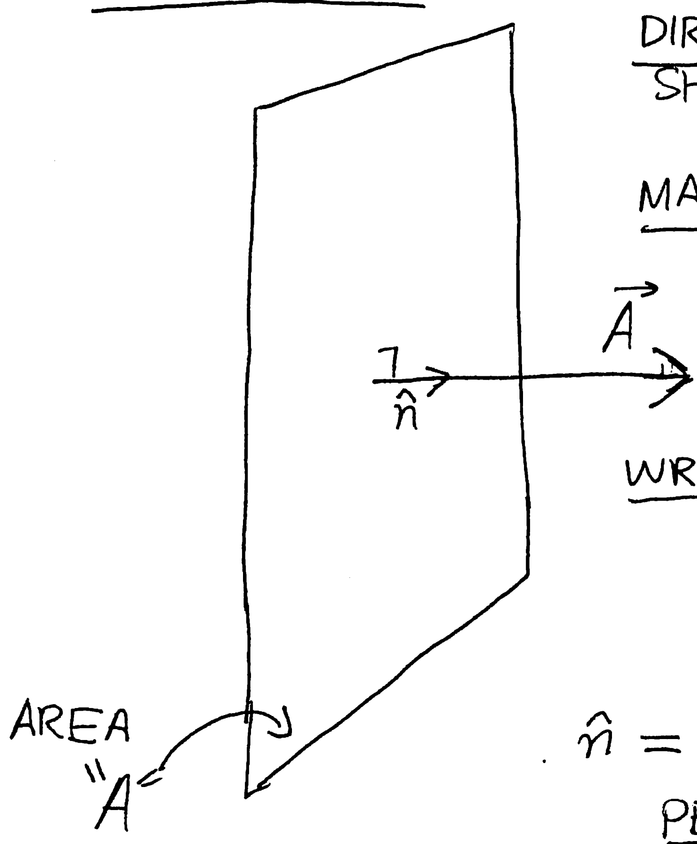
WEEK 2 ELECTRIC FLUX AND GAUSS' LAW

AREA VECTOR



DIRECTION: PERPINDICULAR TO SHEET

MAGNITUDE: AREA OF SHEET

WRITTEN:

$$\boxed{\vec{A} = A\hat{n}}$$

$\hat{n}$ = UNIT VECTOR POINTING PERPINDICULAR TO SHEET

CALLED: NORMAL VECTOR

$\vec{A}$ UNAMBIGUOUSLY TELLS US WHICH WAY THE SHEET IS POINTING.

ELECTRIC FLUX, GAUSS' LAW

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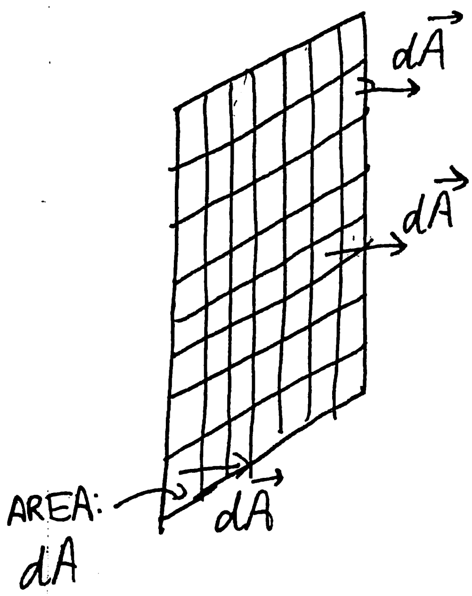
AREA ELEMENT "$d\vec{A}$"

BREAK SHEET UP INTO LITTLE ELEMENTS



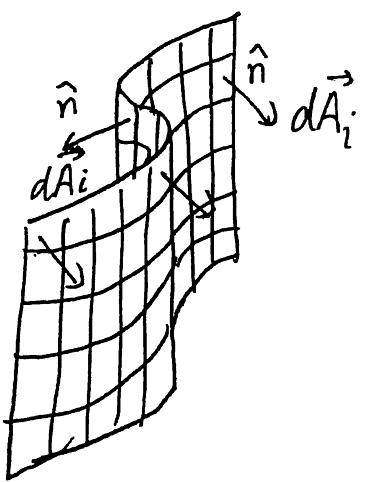
EACH "SMALL" ELEMENT HAS AREA dA WHERE THE "d" INDICATES "DIFFERENTIAL"

$$d\vec{A} = \hat{n}\, dA$$

$$\boxed{\vec{A} = \int d\vec{A}}$$

READ AS: "SUM UP" VECTORIALLY

"NON-SHEETS:"



EACH $d\vec{A}_i$ POINTS IN WHATEVER DIRECTION IS ~~[illegible]~~ PERPINDICULAR TO ELEMENT i

$$\boxed{\vec{A} = \sum_{\substack{i \\ i \to \infty}} d\vec{A}_i = \int d\vec{A}}$$

ELECTRIC FLUX & GAUSS' LAW

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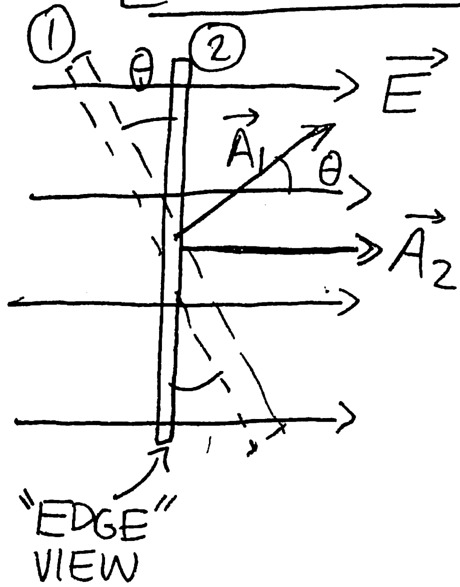
DEFINE ELECTRIC FLUX

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



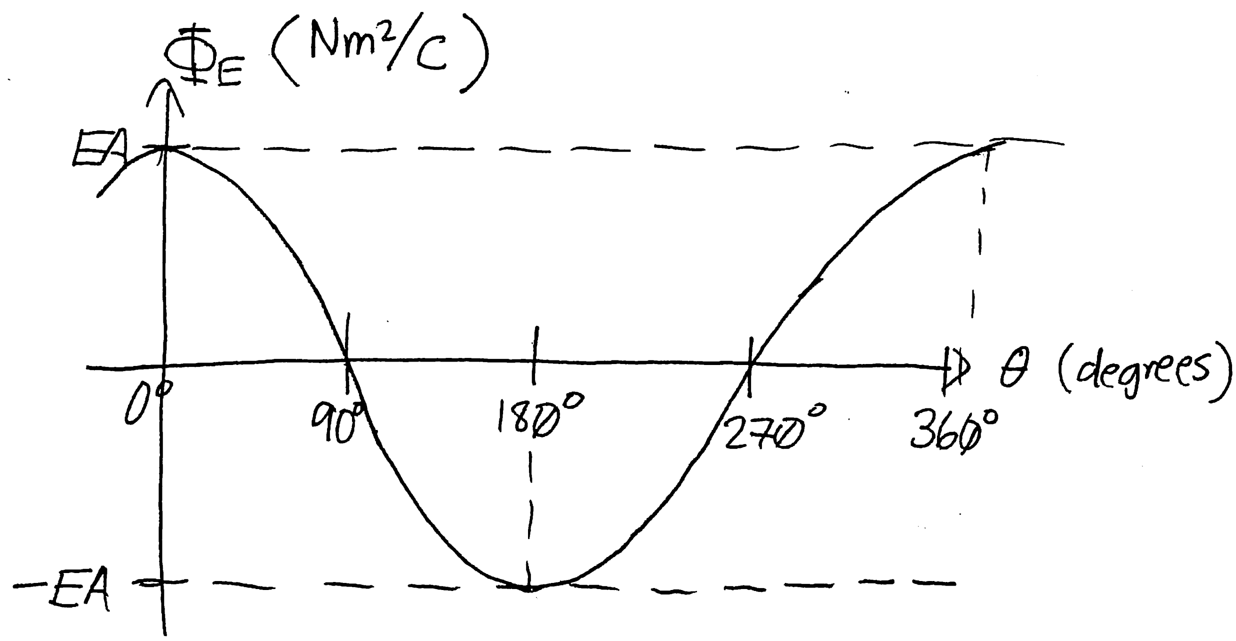
IN POSITION 1, $\theta \neq 0$ SO:

$$(\Phi_E)_1 = EA\cos\theta$$

IN POSITION 2, $\theta = 0$

$\cos\theta = \cos(0) = 1$, SO:

$$(\Phi_E)_2 = EA$$



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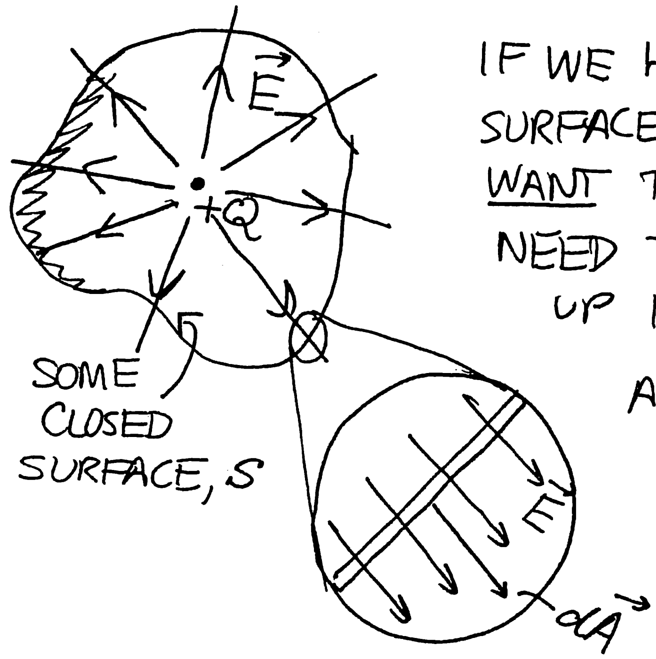

IF WE HAVE SOME ARBITRARY SURFACE THROUGH WHICH WE WANT THE FLUX (TOTAL) WE NEED TO BREAK THE SURFACE UP INTO ELEMENTS W/ AREA VECTORS $d\vec{A}$ AND SUM UP

$$\vec{E} \cdot d\vec{A} = d\Phi_E$$

FOR EACH ELEMENT.

$$\boxed{(\Phi_E)_{TOT} = \int d\Phi_E = \int_S \vec{E} \cdot d\vec{A} = \int_S E\, dA \cos\theta}$$

IF SURFACE IS CLOSED, THEN WE DO A SURFACE INTEGRAL:

$$\boxed{(\Phi_E)_{TOT} = \oint_S \vec{E} \cdot d\vec{A}}$$

THE $\oint$ INTEGRAL SIGN REMINDS US WE ARE SUMMING UP OVER A CLOSED SURFACE.

ELECTRIC FLUX AND GAUSS' LAW

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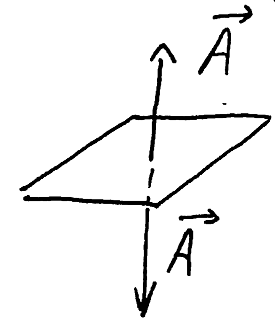
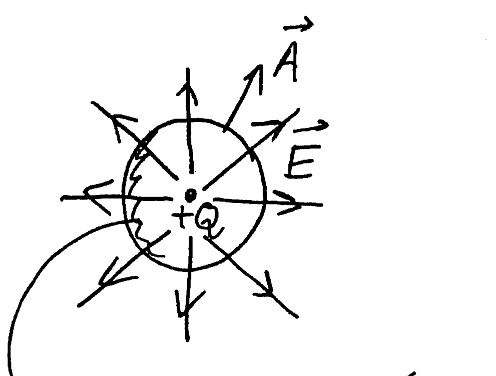
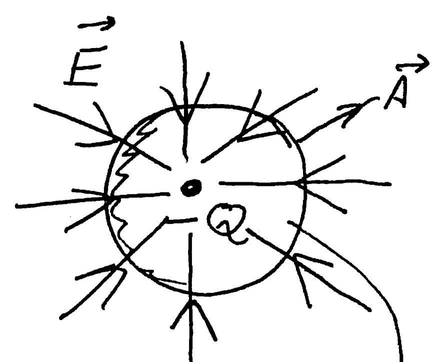
NOTE: ANY SURFACE HAS TWO AREA VECTORS; IT DOESN'T MATTER WHICH WE PICK BUT WE NEED TO BE CONSISTENT.



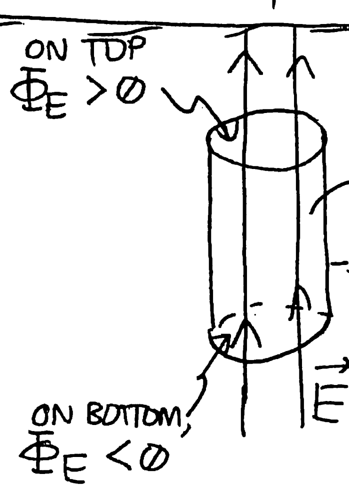
FOR A CLOSED SURFACE, WE ALWAYS USE THE OUTWARD-GOING $\vec{A}$ FOR $\vec{E} \cdot \vec{A}$ OR $\vec{E} \cdot d\vec{A}$



FLUX $\Phi_E > 0$ (+)



FLUX $\Phi_E < 0$ (−)



CLOSED SURFACE: $(\Phi_E)_{TOT} = \oint_S \vec{E} \cdot d\vec{A} = 0$

SINCE AS MANY FIELD LINES ENTER AS EXIT.

ELECTRIC FIELD

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GAUSS' LAW

GAUSS' LAW STATES:

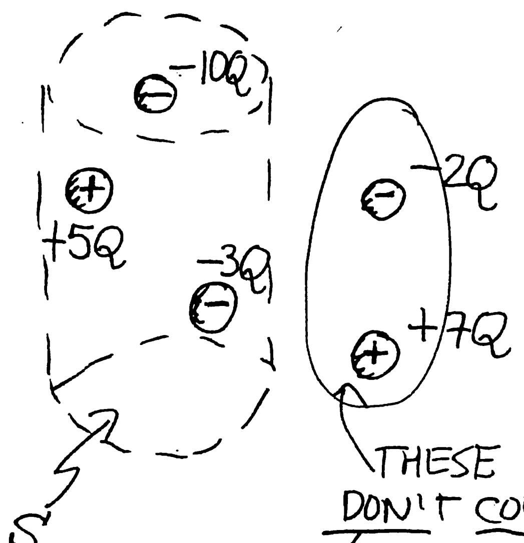
$$\boxed{(\Phi_E)_{TOT} = \oint_S \vec{E} \cdot d\vec{A} = \frac{\Sigma q_{encl}}{\epsilon_0}}$$

1. FIND THE CLOSED SURFACE S
2. ADD UP THE TOTAL, NET CHARGE WITHIN S.
3. RESULT = TOTAL FLUX (TIMES ϵ_0)

EXAMPLE WHAT IS $(\Phi_E)_{TOT}$ THRU THE SURFACE S BELOW?

ANSWER: $\boxed{-\dfrac{8Q}{\epsilon_0}}$

FROM GAUSS.



THESE DON'T COUNT; THEY'RE NOT ENCLOSED.

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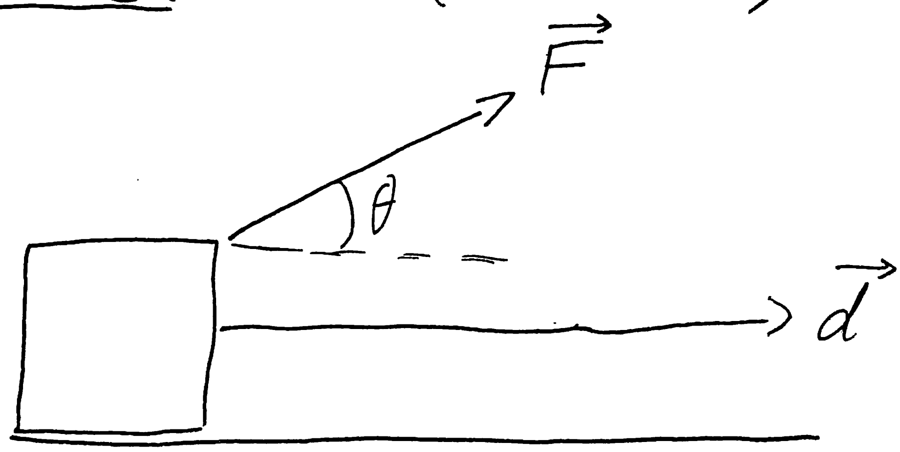
WEEK 3: ELECTRIC POTENTIAL DIFFERENCE

REMINDER: WORK (DEFINITION)



WORK $W = \vec{F} \cdot \vec{d} = Fd\cos\theta$

$\vec{F}_E = q\vec{E}$ IS A FORCE, SO IT CAN DO WORK ALSO.

ELEC. POT. DIFF.

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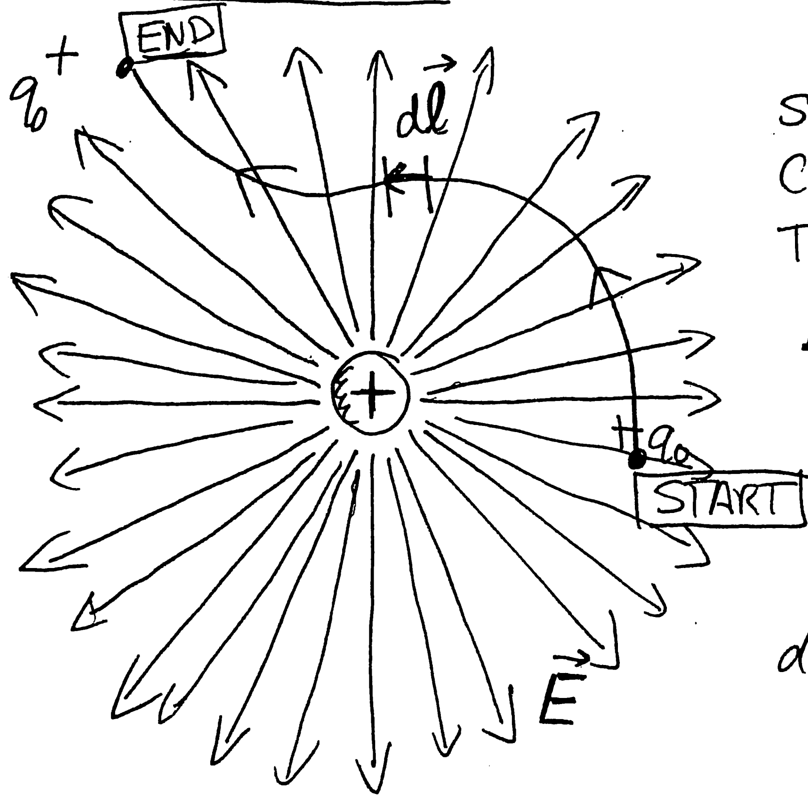


SUPPOSE I PUT TEST CHARGE $+q_0$ IN THE ELECTRIC FIELD $\vec{E}$ SHOWN AND DRAG IT FROM $\boxed{\text{START}}$ TO $\boxed{\text{END}}$.

$d\vec{\ell}$ = "LITTLE ELEMENT" OF PATH

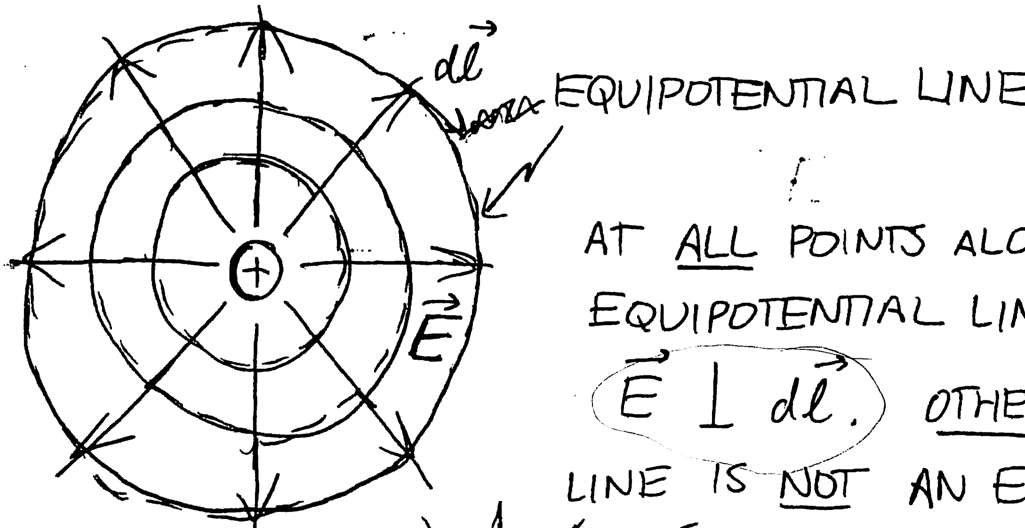
$$\vec{F}_E = q_0\vec{E} \quad \text{AND} \quad W_E = \int_{\boxed{\text{START}}}^{\boxed{\text{END}}} \vec{F}_E \cdot d\vec{\ell}$$

THEREFORE,

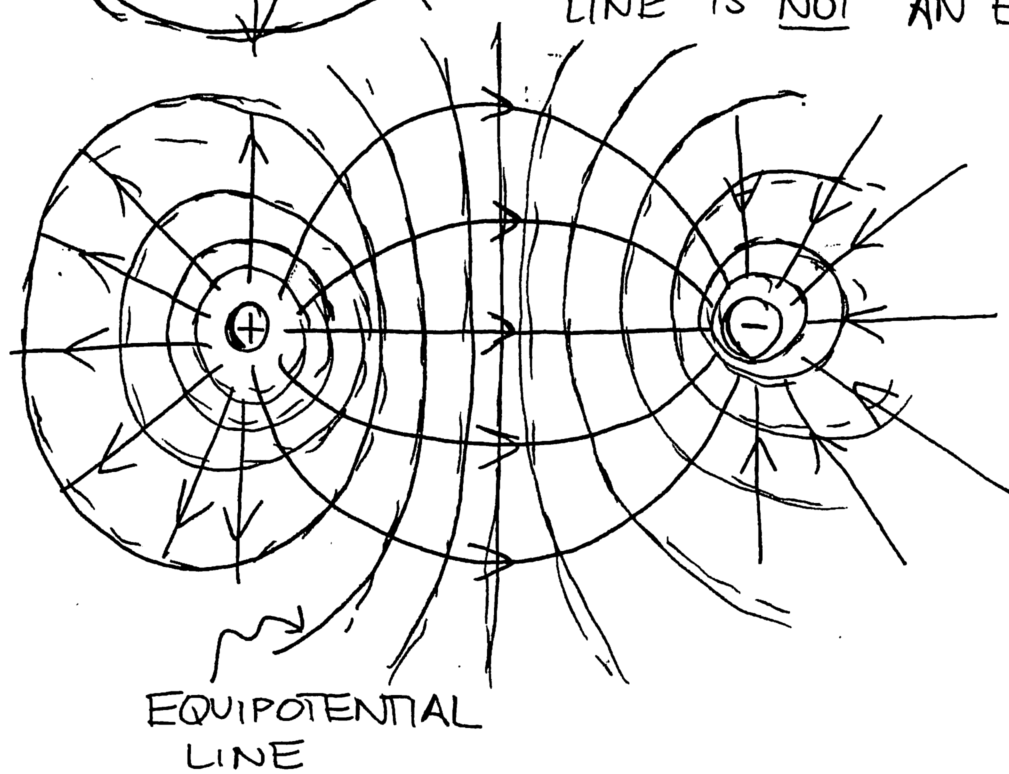
$$\boxed{W = q_0 \int_{\boxed{\text{START}}}^{\boxed{\text{END}}} \vec{E} \cdot d\vec{\ell}}$$

WHEN $\vec{E} \perp d\vec{\ell}$ ALWAYS FOR A CERTAIN PATH, $\vec{E} \cdot d\vec{\ell} \equiv 0$ SO $W = 0$ ALONG PATH

SUCH A PATH, ALONG THE WHOLE OF WHICH $W = 0$, IS CALLED AN <u>EQUIPOTENTIAL LINE</u> OF $\vec{E}$.



AT <u>ALL</u> POINTS ALONG AN EQUIPOTENTIAL LINE IS $\vec{E} \perp d\vec{l}$. <u>OTHERWISE</u>, LINE IS <u>NOT</u> AN EQUIPOTENTIAL.



ELECTRICAL POT. DIFFERENCE

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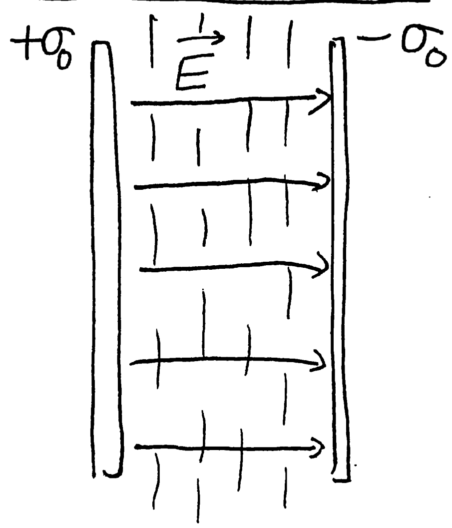
PARALLEL PLATES



EQUIPOTENTIAL LINES ARE ALL PARALLEL TO PLATES.

$W = q_0 \int \vec{E} \cdot d\vec{l}$ IS WORK DONE BY FIELD, $\vec{E}$, ON TEST CHARGE q_0.

POTENTIAL ENERGY OF TEST CHARGE, ΔU:

$W = -\Delta U$

$$\Rightarrow \boxed{\Delta U = -q_0 \int_{\text{START}}^{\text{END}} \vec{E} \cdot d\vec{l} = q_0 \Delta V}$$

ΔV = POTENTIAL DIFFERENCE

Electrical Potential Difference

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$$\Delta V = -\frac{W}{q_0} = -\frac{\cancel{q_0}\int \vec{E}\cdot d\vec{l}}{\cancel{q_0}}$$

$$\boxed{\underline{\underline{SO}} \quad \Delta V_{AB} = -\int_{A}^{B} \vec{E}\cdot d\vec{l}}$$

POTENTIAL DIFFERENCE BETWEEN POINTS A AND B

Recall ~~en~~ Energy Conservation

ENERGY = KINETIC + POTENTIAL ENERGY = FIXED

OR:

$$\boxed{E = K + U = \text{FIXED}}$$

$$W = \Delta K = \frac{1}{2}m\left(v_{final}^2 - v_{initial}^2\right)$$

Kinetic Energy

$$-W = \Delta U = q_0 \Delta V_{AB} = -q_0 \int_{A}^{B} \vec{E}\cdot d\vec{l}$$

Potential energy

Total Energy = $\Delta K + \Delta U$

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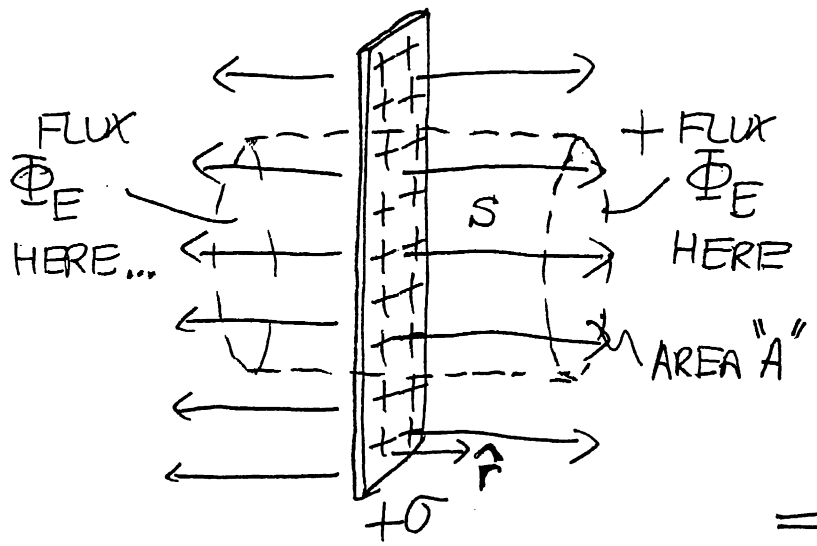
WEEK 4 : CAPACITANCE

FIELD OF A SHEET CHARGE



$$\oint_S \vec{E} \cdot d\vec{A} = \frac{\Sigma Q_{encl}}{\epsilon_0}$$

$$\Sigma Q_{encl} = \sigma A$$

$$\oint_S \vec{E} \cdot d\vec{A} = 2EA$$

$$\Rightarrow 2E\cancel{A} = \frac{\sigma \cancel{A}}{\epsilon_0}$$

FIELD IS:

$$\boxed{\vec{E} = \frac{\sigma}{2\epsilon_0}\hat{r}}$$ FOR SINGLE SHEET

THIS IS "UNIFORM"; HAS THE SAME MAGNITUDE NO MATTER WHERE YOU ARE

CAPACITANCE

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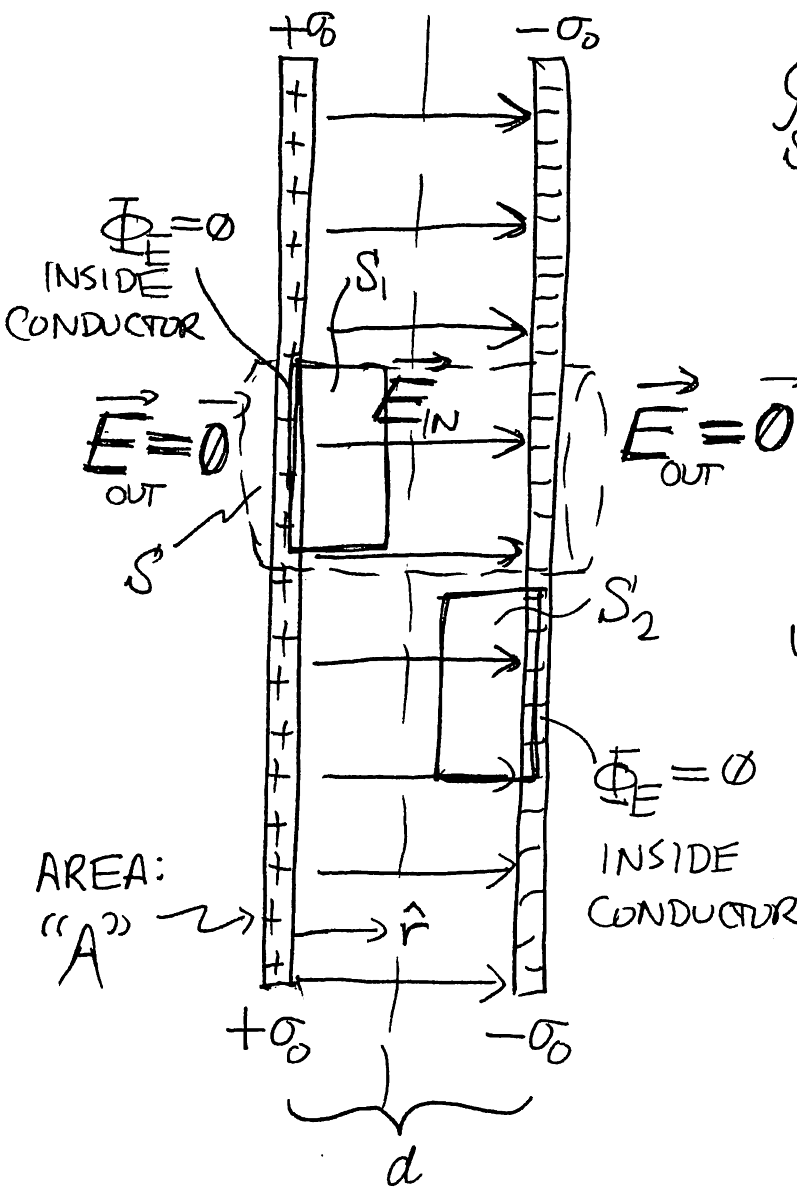
FOR TWO PARALELL PLATES:



$$\oint_S \vec{E} \cdot d\vec{A} = \frac{\sum Q_{encl}}{\epsilon_0}$$

$$EA = \frac{\sigma A}{\epsilon_0}$$

$$\Rightarrow \boxed{E_{IN} = \frac{\sigma}{\epsilon_0}}$$

USE GAUSSIAN SURFACES S_1, S_2

$$\boxed{\vec{E}_{IN} = \frac{\sigma}{\epsilon_0}\hat{r}}$$

THIS FIELD IS ALSO UNIFORM!

CAPACITANCE

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NOTES:

- ANY TWO PARALLEL PLATES FORM A "CAPACITOR." SYMBOL: OR

- SUPERPOSITION REFERS TO ADDING UP $\vec{E}$ FIELDS VECTORIALLY.

$$\sigma = \frac{\text{charge}}{\text{area}} = \text{"charge density"} = \frac{Q}{A}$$

FOR A CAPACITOR W/ CAPACITANCE C AND POTENTIAL DIFFERENCE ΔV BETWEEN ITS PLATES, CHARGE Q ON PLATES IS:

$$Q = C\Delta V$$

(SAY IT FAST: "Q EQUALS CEE-VEE")

FOR PARALLEL PLATES OF AREA A SPACED A DISTANCE d APART,

$$\boxed{C = \frac{Q}{\Delta V} = \frac{\epsilon_0 A}{d}}$$

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$C = \frac{\epsilon_0 A}{d}$ COMES FROM:

1. $\Delta V = Ed = \frac{\sigma}{\epsilon_0} d$ (SINCE $\vec{E}$ IS UNIFORM)

2. $Q = \sigma A$ SINCE $\sigma \equiv \frac{Q}{A}$

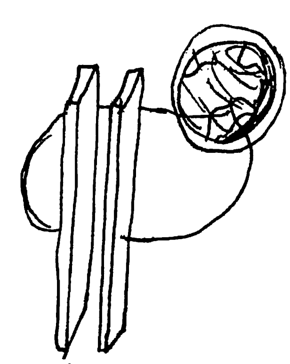
FROM $Q = C\Delta V$, WE GET:

$$C = \frac{Q}{\Delta V} = \frac{\cancel{\sigma} A}{\cancel{\sigma} d/\epsilon_0} = \frac{\epsilon_0 A}{d} \checkmark$$

NOTICE: $\Delta V \propto d$, AND $C \propto A$, $C \propto \frac{1}{d}$

SO CAPACITANCE GOES DOWN AS DISTANCE BETWEEN PLATES GOES UP

CAPACITANCE GOES UP AS AREA OF PLATES GOES UP



EARTH'S BIGGEST CAPACITOR?

CAPACITANCE

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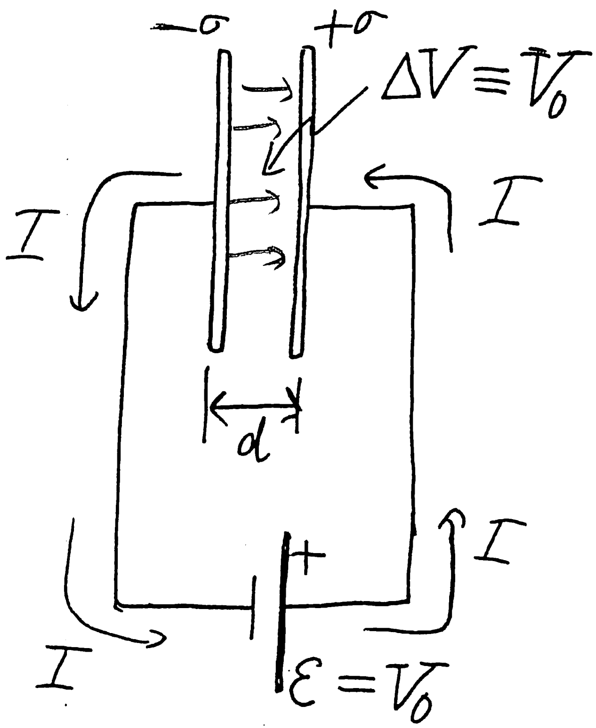
WITH A BATTERY, CAPACITOR STAYS CHARGED:



BATTERY SUPPLIES OR REMOVES CHARGE AS APPROPRIATE SO AS TO KEEP $\Delta V \equiv V_0$

$$\Delta V = Ed \equiv V_0$$

SO NOW IF $E \uparrow$, $d \downarrow$ AND VICE-VERSA.

~~OTHERWISE~~ THEREFORE, σ, TOO, CHANGES DEPENDING ON d.

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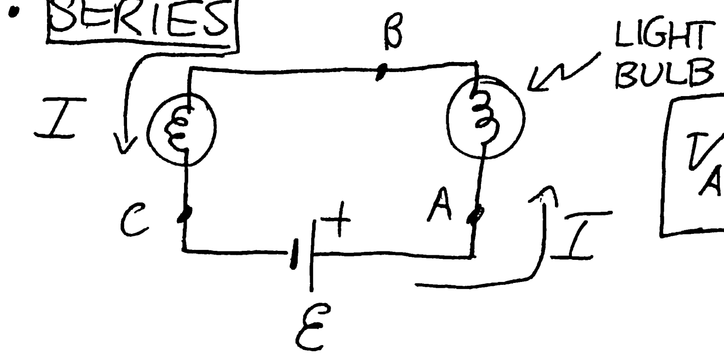
WEEK 6: BASIC CIRCUITS

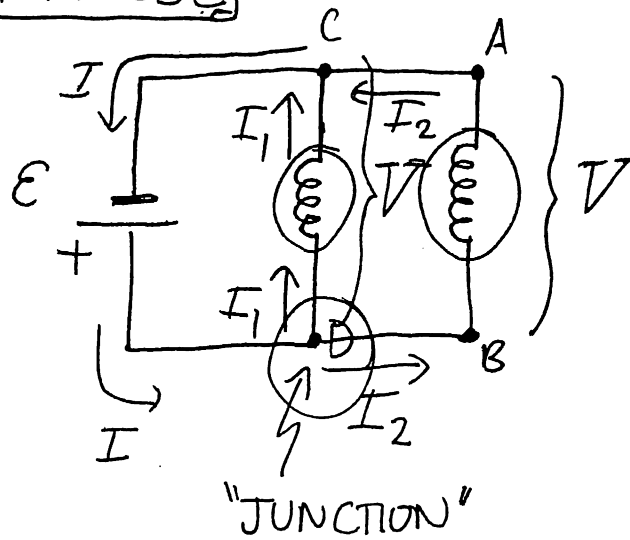
CIRCUITS COME IN 2 TYPES:

- SERIES



$$\boxed{V_{AC} = \mathcal{E} = V_{AB} + V_{BC}}$$

- PARALLEL



$$\boxed{V_{AB} = V_{CD} = \mathcal{E}}$$

$$\boxed{I = I_1 + I_2}$$

IN SERIES, CURRENT I IS THE SAME AT ALL POINTS. VOLTAGES ADD UP TO $\mathcal{E}$.

IN PARALLEL, CURRENTS ADD UP TO I, AND ALL VOLTAGES ARE EQUAL

COM port in
The Ammeter is
on the lower potential

BASIC CIRCUITS

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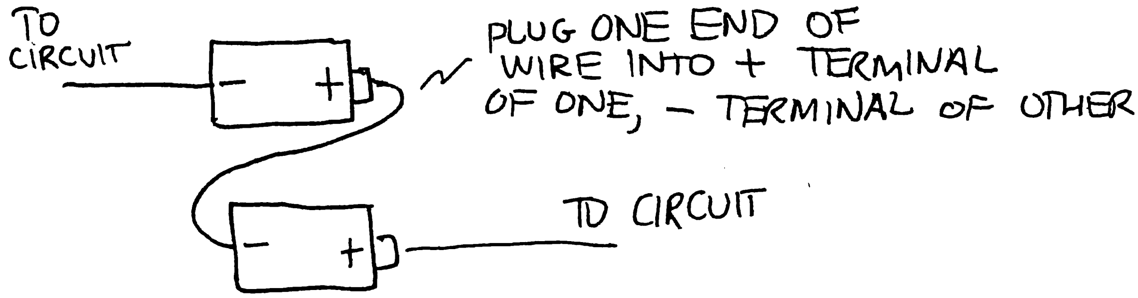
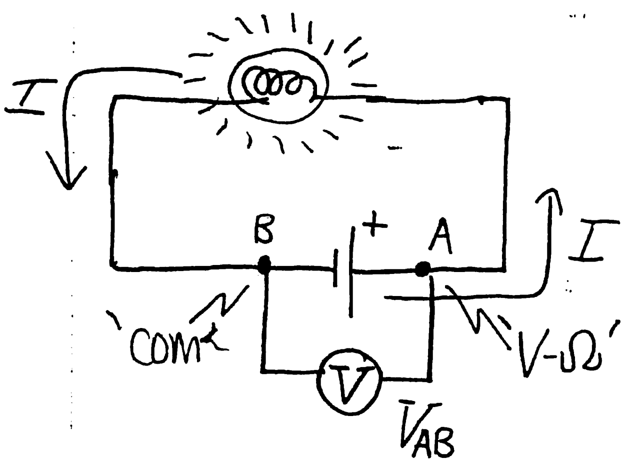
HOW TO CONNECT TWO BATTERIES IN SERIES:

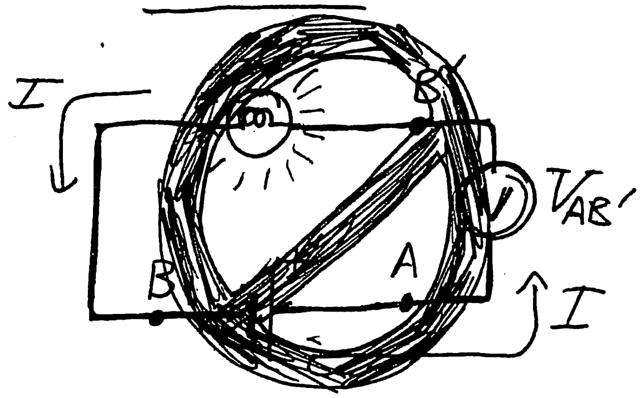


CONNECT VOLTMETERS IN PARALLEL WITH WHAT TO MEASURE! NEVER IN SERIES:

CORRECT



INCORRECT



A SOURCE, $\mid\mid^{+}$, LIKE A BATTERY, GIVES US A RISE IN THE ELECTRIC POTENTIAL.

LIGHT BULBS GIVE US A DROP IN THE POTENTIAL.

BASIC CIRCUITS

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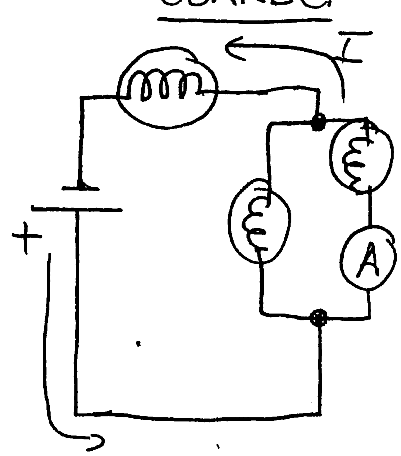
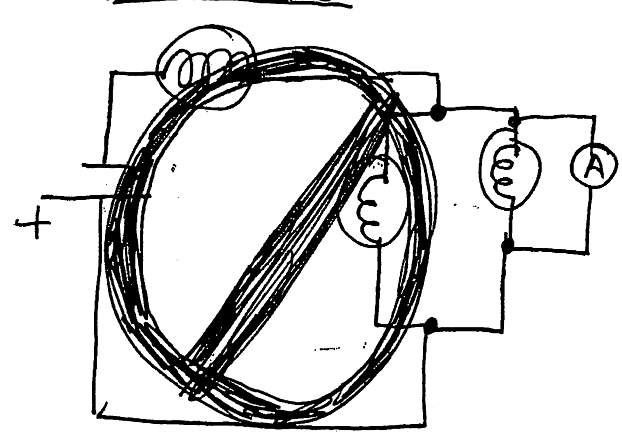
SIDE OF CIRCUIT W/ HIGHER POTENTIAL GETS CONNECTED TO THE RED, 'V-Ω' PLUG ON VOLTMETER; 'COM' PORT IS CONNECTED TO SIDE OF CIRCUIT GOING BACK TO THE BATTERY.

CONNECT AMMETERS IN SERIES WITH WHAT YOU WANT TO MEASURE! NEVER IN PARALLEL:

CORRECT



INCORRECT



NOW, FOR AMMETERS, INPUT IS NOT THE 'V-Ω' ~~SWITCH~~ PORT BUT THE 'A' PORT.

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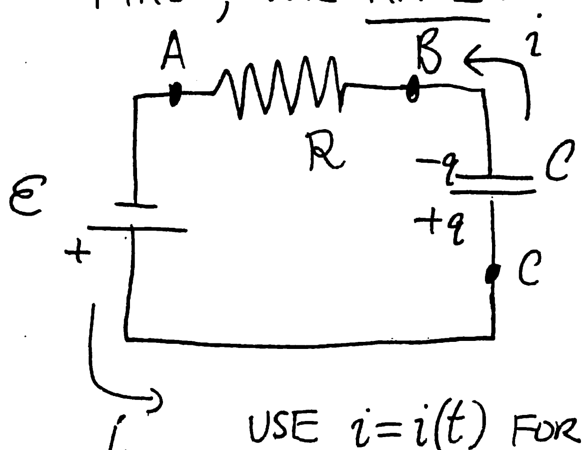
WEEK 7: RC CIRCUITS

RC CIRCUITS: CIRCUITS WHERE THERE ~~ARE~~ IS A RESISTOR (E.G. A LIGHT BULB) & A CAPACITOR CONNECTED IN SERIES.

FIRST, WE HAVE:



R : LIGHT BULB

C : CAPACITOR

ASK: WHAT ARE VOLTAGES, CURRENTS AS FUNCTIONS OF TIME?

USE $i = i(t)$ FOR CURRENT
$q = q(t)$ FOR CHARGE ON PLATES.

AT TIME $t = 0$,

$$v_{BAT.} = \mathcal{E} \qquad v_R = v_{AB} = iR \qquad v_C = v_{BC} = 0$$

AFTER A "LONG" TIME $(t \to \infty)$

$$v_{BAT.} = \mathcal{E} \qquad v_R = v_{AB} = 0 \qquad v_C = v_{BC} = \frac{q}{C} = \frac{Q_f}{C}$$

WHERE Q_f IS FINAL CHARGE ON CAPACITOR PLATES.

$$Q_f = C\mathcal{E} = C v_{BAT.}$$

R–C CIRCUITS

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FROM KIRCHHOFF,

$$\sum V_{loop} = 0$$

OR

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

$$\Longleftrightarrow \quad i = \frac{\mathcal{E}}{R} - \frac{q}{RC} \qquad \text{BUT} \quad i \equiv \frac{dq}{dt}$$

OR :

$$\boxed{\frac{dq}{dt} = -\frac{1}{RC}(q - C\mathcal{E})} \qquad \text{(CHARGING)}$$

THIS IS A DIFF. EQ. TO SOLVE :

$$\int_0^q \frac{dq'}{q' - C\mathcal{E}} = -\int_0^t \frac{dt'}{RC} \qquad \text{SEPARATE VARIABLES}$$

$$\Rightarrow \ln\left(\frac{q - C\mathcal{E}}{-C\mathcal{E}}\right) = -\frac{t}{RC} \qquad \text{INTEGRATE}$$

$$\Rightarrow \frac{q - C\mathcal{E}}{-C\mathcal{E}} = e^{-t/RC} \qquad \text{TAKE exp( ) OF BOTH SIDES}$$

$$\Rightarrow \boxed{Q_{charge}(t) = Q_f\left(1 - e^{-t/RC}\right)} \qquad \text{REARRANGE}$$

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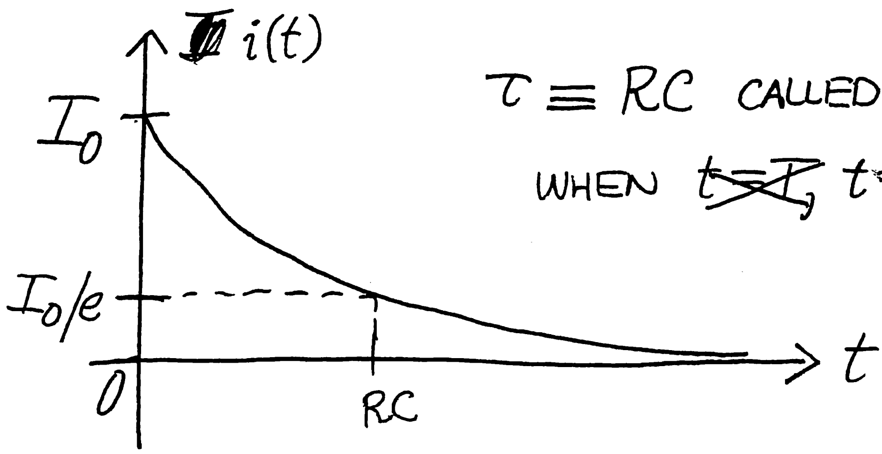
BY DEFINITION:

$$i(t) = \frac{dQ}{dt} = \frac{d}{dt}\left(Q_f\left(1-e^{-t/RC}\right)\right)$$ DIFFERENTIATE

OR:

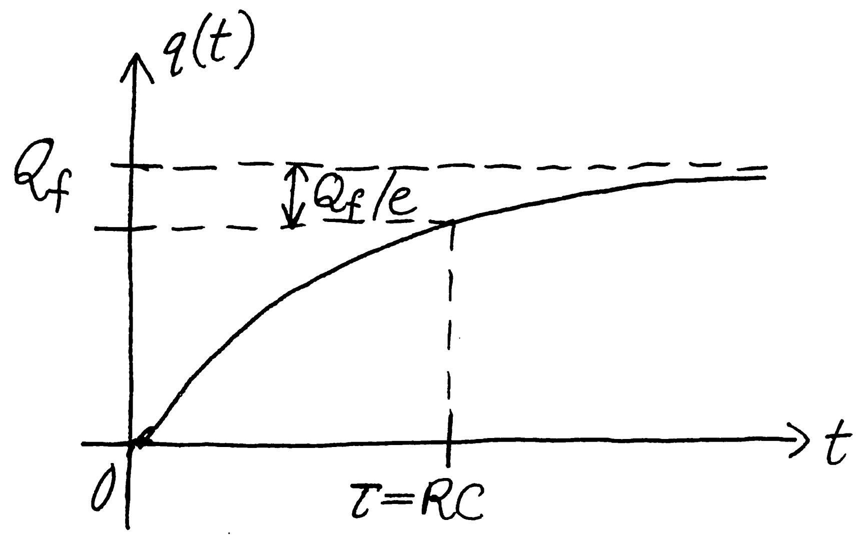
$$\boxed{i(t) = \frac{\mathcal{E}}{R}e^{-t/RC} = I_0 e^{-t/RC}}$$

FOR CHARGING, WE PLOT:



$\tau \equiv RC$ CALLED TIME CONSTANT

WHEN ~~$t=T$~~, $t=\tau$, $i(t)=I_0e^{-1}$



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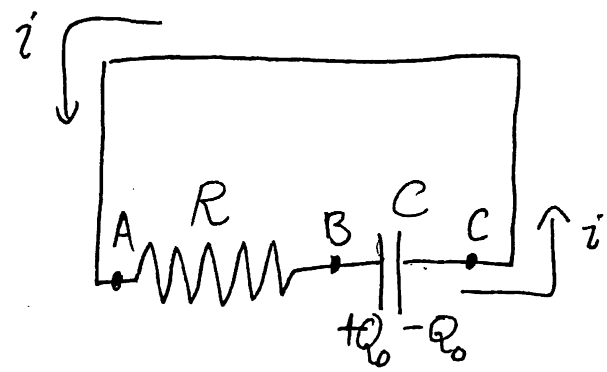
DISCHARGING THE CAPACITOR

REMOVE THE SOURCE, $\mathcal{E}$, FROM CIRCUIT! (~~FROW~~ THROW A SWITCH)



AT TIME $t = \emptyset$, WE HAVE:

~~$v_R = v_{AB} = \emptyset$ SINCE~~

$$v_R = v_{AB} = I_0 R \qquad v_C = v_{BC} = \frac{Q_0}{C} \qquad Q_0 \neq Q_f$$

in general

AFTER A "LONG" TIME $(t \to \infty)$

$$v_R = v_C = \emptyset \quad i = 0 \quad q = 0$$

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FROM KIRCHHOFF, $\sum V_{LOOP} = \emptyset$, SO:

$$iR + \frac{q}{C} = \emptyset \qquad \text{(NOW CAPACITOR IS A SOURCE)}$$

$$\Rightarrow \boxed{i = \frac{dq}{dt} = \frac{-q}{RC}} \longleftarrow \text{DIFF. EQ. TO SOLVE}$$

$$\Rightarrow \int_0^q \frac{dq'}{q'} = -\int_0^t \frac{dt}{RC}$$

$RC \equiv \tau = \text{const.}$
SEPARATE VARIABLES

$$\Rightarrow \ln \frac{q}{Q_0} = -\frac{t}{RC}$$

INTEGRATE

$$\Rightarrow \boxed{q = Q_0 e^{-t/RC}}$$

$\exp(x) = e^x \quad \exp(\ln(x)) = x$
TAKE $\exp(\;)$ OF BOTH SIDES AND SIMPLIFY

DIFFERENTIATE TO GET $i = i(t)$:

$$\boxed{i(t) = \frac{dq}{dt} = -\frac{Q_0}{RC} e^{-t/RC} = -I_0 e^{-t/RC}}$$

THESE RESULTS ARE FOR DISCHARGING THE CAPACITOR.

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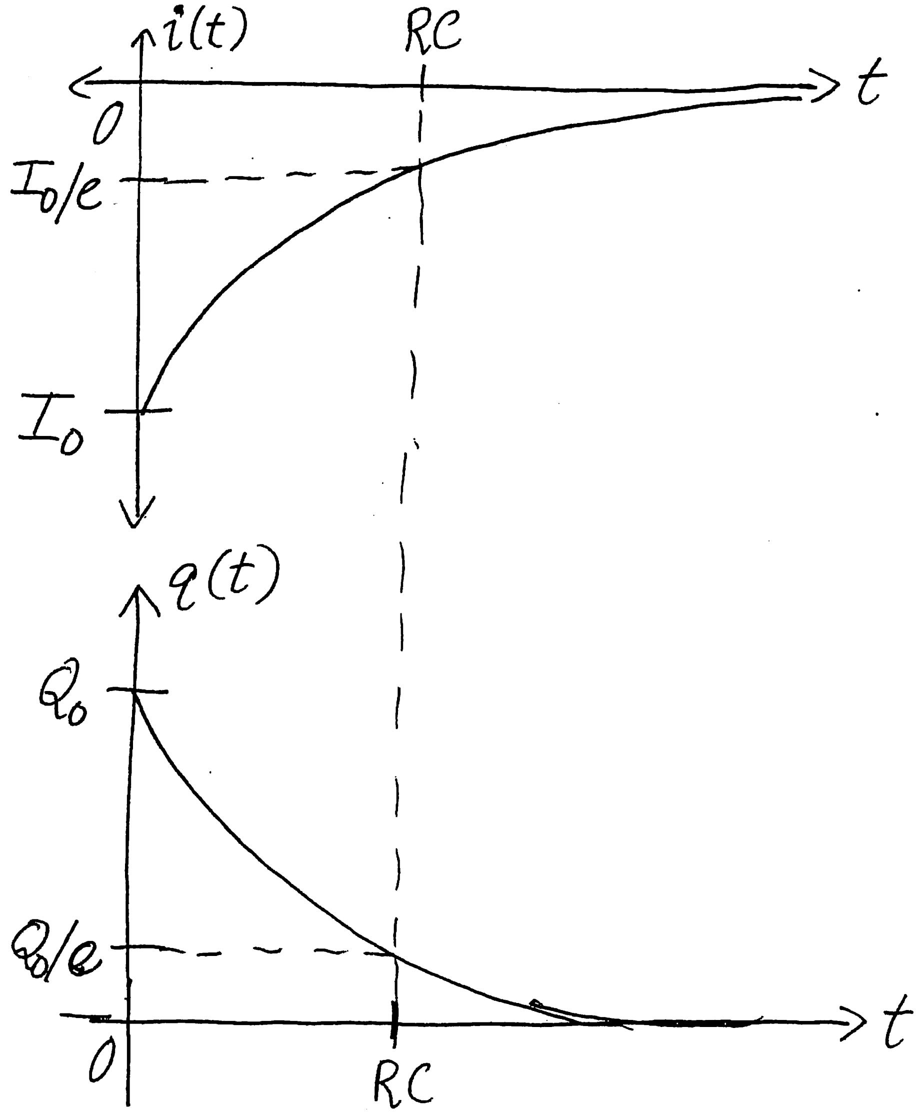
WE PLOT, FOR DISCHARGING,



PHYSICS 7LD LAB NOTES
SUMMER SESSION II – 2003 – UCI

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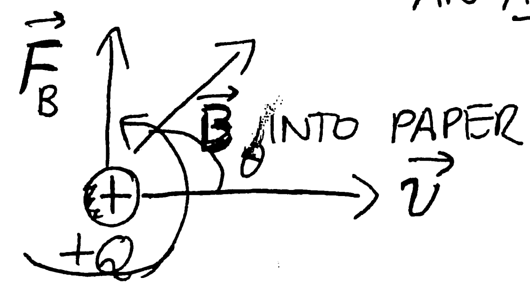
WEEK 8: MAGNETIC FIELDS

WE JUST FINISHED LOOKING AT THE ELECTRIC FIELD, $\vec{E}$.

MAGNETIC FIELD "$\vec{B}$"

PRODUCED BY A MOVING CHARGE OR BY A CURRENT-CARRYING WIRE.

DENOTE WITH $\vec{B}$. FOR CHARGE $+Q$ MOVING IN AN APPLIED FIELD:



"RIGHT-HAND" RULE.

$$\boxed{\vec{F}_B = Q(\vec{v} \times \vec{B})}$$

$$F_B = QvB\sin\theta$$

& DIRECTION FROM RIGHT-HAND RULE.

WRITE $\vec{J} = Q\vec{v}$ "CURRENT VECTOR"

THEN $\boxed{\vec{F}_B = \vec{J} \times \vec{B}}$

MAGNETIC FIELDS

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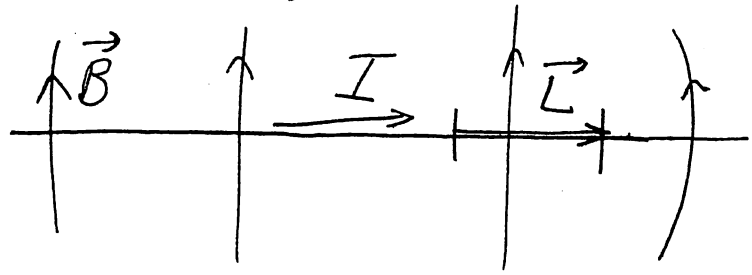
FOR LONG, CURRENT-CARRYING CONDUCTOR,

DENOTE BY $\vec{L}$ DIRECTION THE CURRENT, I FLOWS. $|\vec{L}|$ = length of wire.



MAGNETIC FORCE ON WIRE IS:

$$\boxed{\vec{F}_B = I\vec{L} \times \vec{B}}$$

"FIB" RULE

AGAIN, WE CAN WRITE A "CURRENT VECTOR"

$$\vec{J} = I\vec{L}$$

AND $\vec{F}_B = \vec{J} \times \vec{B}$

BUT $\vec{J}$ IS NEVER USED, SO PUT "$I\vec{L}$".

REMEMBER, IT'S $\vec{J}$ AND $\vec{L}$, NOT I, THAT ARE THE VECTOR QUANTITIES!

$\boxed{I \text{ IS } \underline{\text{NEVER}} \text{ A VECTOR.}}$

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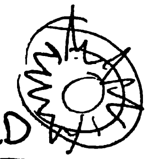
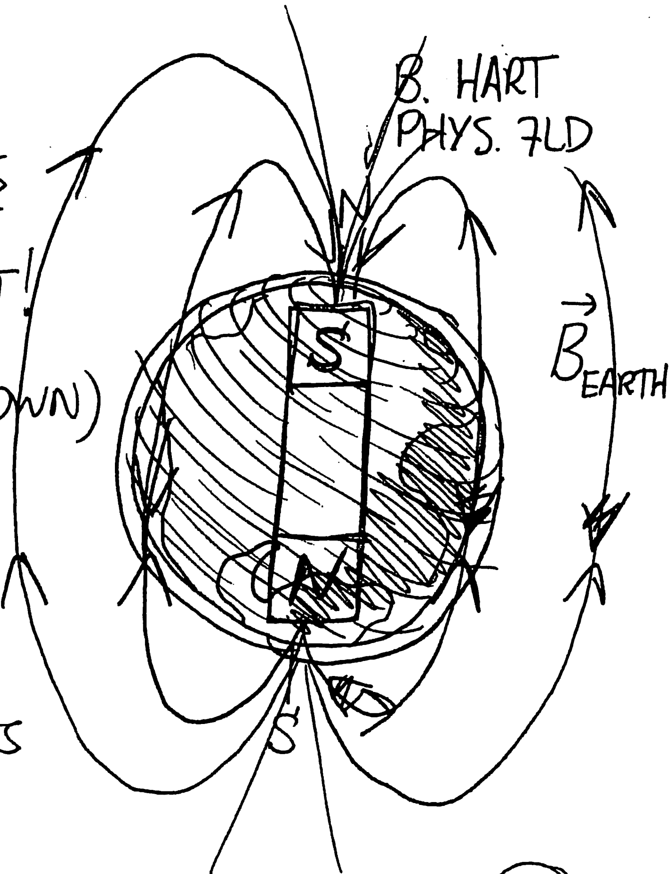
MAGNETIC FIELD



BAR MAGNETS, SOLENOIDS

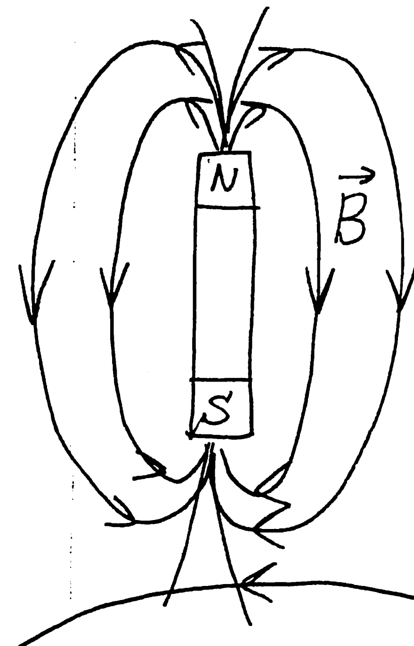
EARTH IS A BAR MAGNET!

(CURRENTLY UP-SIDE DOWN)



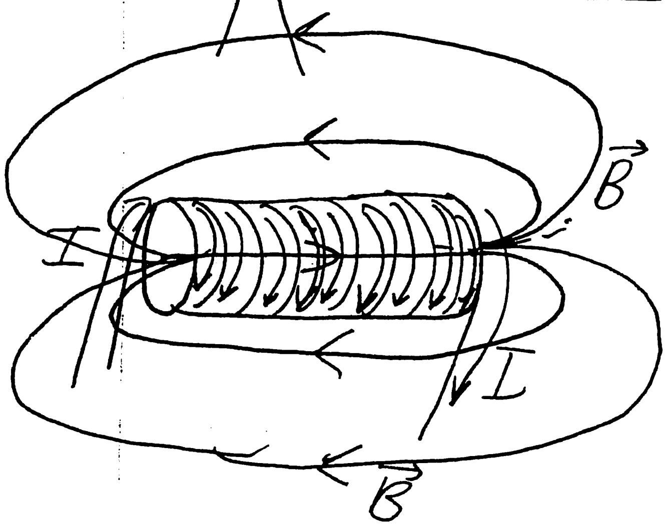
CAUSES:

- NORTHERN LIGHTS
- SOUTHERN LIGHTS
- COMMUNICATIONS BLACKOUTS DURING SOLAR FLARES



N, S POLE NAMES DO NOT HAVE ANYTHING TO DO W/ DIRECTIONS

UNLIKE POLES ATTRACT, LIKES REPEL



SOLENOID: FIELD GOES DOWN AXIS; EXTERNALLY, LOOKS LIKE A BAR MAGNET

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WEEK 9 : LENZ' AND FARADAY'S LAWS

FARADAY'S LAW

$$\mathcal{E} = \oint_{\text{WIRE LOOP}} \vec{E} \cdot d\vec{l} = -\frac{d\Phi_B}{dt}$$

→ IF I PUT A WIRE LOOP OF RESISTANCE R IN A FIELD $\vec{B}$ AND CHANGE Φ_B THROUGH THE WIRE

⇒ A CURRENT $I = \frac{\mathcal{E}}{R}$ ARISES IN THE WIRE

WTF IS Φ_B??

weber $\Phi_B = \vec{B} \cdot \vec{A}$ = "MAGNETIC FLUX"

JUST LIKE ELECTRIC FLUX.

$\oint_S \vec{B} \cdot d\vec{A} \equiv 0$, SAYS GAUSS, WHERE S IS A CLOSED SURFACE.